FRESNO COMMUNITY ENVIRONMENTAL HEALTH IMPACT ASSESSMENT

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COMMUNITY AND LABOR CENTER
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UNIVERSITY OF CALIFORNIA, MERCED

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Lastly, we thank the California Department of Public Health Office of Vital Statistics and the California Department of Health Care Access and Information for granting us permission to use their data, as well as the Fresno residents who contributed to these data.

EXECUTIVE SUMMARY

Fresno County has some of the nation's greatest environmental inequalities. In 2022, Fresno had the highest short-term particle pollution, second highest year-round particle pollution, and fourth highest ozone pollution in the nation. Assembly Bill 617, effective in 2017, created the Community Air Protection Program (CAPP), to more effectively reduce pollution exposure and preserve public health. This bill directs the California Air Resources Board (CARB) and all local air districts, including the San Joaquin Valley Air Pollution Control District, to take measures to protect communities who are disproportionately impacted by air pollution.

In 2022, the San Joaquin Valley Air Pollution Control District (hereafter the Air District) and the City of Fresno collaborated to undertake the South-Central Fresno AB 617 Community Truck Reroute Study. The aim of the study is to identify, analyze, and evaluate potential strategies that the city might implement, in cooperation with freight-impacted communities, to abate truck impacts (e.g., health, pollution, noise, etc.). In the same year, the City of Fresno commissioned the UC Merced Community and Labor Center to conduct a Health Impact Assessment (HIA) in Fresno. The results of the Fresno HIA, presented in this report, are intended to inform the ongoing South Fresno Truck Reroute Study

The Fresno HIA has two main components. The first is a large, city-wide assessment. This assessment contains air district data, birth data, emergency department visits, as well as all Fresno patient discharge data. The second Fresno HIA component is the South Fresno Community Survey, which is a representative, community-based survey of South Fresno residents' health, wellbeing, and concerns with local environmental issues.

KEY FINDINGS:

Part 1: Population-Based Assessment

» South Fresno residents were, on average, more likely to live closer to a major street, truck route, or freeway.

» Exposures to air pollutants such as fine particles <2.5 microns ($PM_{2.5}$), ozone, and diesel, were associated with higher risk of the following: preterm birth, infant mortality, and emergency room visits or hospitalization due to asthma, or diseases related to the blood vessels of the heart and brain (e.g. heart attack, stroke, etc.).

» Pregnant people who lived within 1,000 feet of a freeway, 1,000 feet of a truck route, or 300 feet of a major road had significantly higher risk of adverse pregnancy outcomes, including preterm birth and infant mortality.[1]

» Preterm birth, infant mortality, and asthma rates were higher among residents in the South Fresno community boundaries compared to the rest of the city.

» Even at the same level of exposure, residents within the South Fresno community boundaries and communities of color experienced higher health risks.

» The effects of $PM_{2.5}$ were stronger in the cold season (November-April) whereas the effects of ozone were stronger in the warm season (May-October).

Part 2: South Fresno Community Survey

» Among residents within the South Fresno community boundaries, there is a high level of environmental health concern related to road conditions, pollution, and climate change.

» Most South Fresno residents support local efforts to direct trucks away from local residential areas.

» Almost half of residents (43%) reported having at least one chronic health condition.

» Over a quarter of women of reproductive age (18-46 years) reported having an adverse pregnancy outcome, such as miscarriage (22%), stillbirth (3%), infant mortality (0.8%), or having a child with a birth defect (1.6%).

» A significant proportion of residents reported that they “sometimes, “often,” or “always” were unable to rest because of air pollution (61%) and traffic/truck noise (49%). These residents were more likely to have health problems.

» Residents who lived within 1,000 feet of a truck route, freeway, or major road had a higher prevalence of chronic health conditions and adverse pregnancy outcomes.[1]

[1] These distances best distinguish the risks among residents inside and outside the buffers. As such, our findings do not suggest those living outside of this buffer have negligible risks.

KEY RECOMMENDATIONS:

» The South-Central Fresno AB 617 Community Truck Reroute Study should propose options that minimize, to the greatest degree possible, truck routes and traffic within 1,000 feet of residential areas.

» A more conservative buffer should be considered, given that residents within the South Fresno AB 617 community, and communities of color, bear higher health risks for the same exposures to pollution.

» Implement season-specific strategies to mitigate truck emissions. Acute exposure was shown to have significant health impacts. The summer presented the greatest risk for exposure to ozone, while the winter presented the greatest risk for exposure to $PM_{2.5}$ particles.

» The use of zero-emission commercial trucks is also recommended to reduce population exposures to air pollution.

RESUMEN EJECUTIVO

El condado de Fresno tiene algunas de las mayores desigualdades medioambientales del país. En 2022, Fresno tenía la mayor contaminación por partículas a corto plazo, la segunda mayor contaminación por partículas durante todo el año y la cuarta mayor contaminación por ozono de la nación. El Proyecto de Ley de la Asamblea 617, aplicada en 2017, creó el Programa de Protección del Aire de la Comunidad (CAPP por sus siglas en inglés), para reducir ser expuesto a la contaminación y cuidar la salud pública. Este proyecto de ley ordena a El Consejo de Recursos del Aire de California (CARB por sus siglas en inglés) y a todos los distritos locales del aire, incluido el Distrito de Control de la Contaminación del Aire del Valle de San Joaquín (en adelante, Distrito del Aire), que tomen medidas para proteger a las comunidades que se ven desproporcionadamente afectadas por la contaminación del aire.

En 2022, el Distrito de Aire y la ciudad de Fresno trabajaron juntos en el Estudio de Desvío de Camiones de la comunidad AB 617 del sur-centro de Fresno, con el fin de identificar, analizar y evaluar las posibles estrategias que la ciudad podría aplicar, con la ayuda de las comunidades afectadas por el transporte de carga, para reducir los impactos de los camiones (por ejemplo, la salud, la contaminación, el ruido, etc.). Ese mismo año, la ciudad de Fresno encargó al Centro Comunitario y Laboral de UC Merced que realizara una Evaluación del Impacto sobre la Salud (EIS) en Fresno. El propósito de los resultados de la EIS de Fresno, presentados aquí son para informar el estudio sobre la desviación de camiones del sur de Fresno.

La EIS de Fresno tenía dos secciones principales: 1) una evaluación amplia en toda la ciudad sobre los datos del distrito del aire, datos de nacimientos y visitas al departamento de urgencias y datos de altas de pacientes entre todos los residentes de Fresno; y 2) una encuesta representativa, basada en la comunidad 617, sobre la salud, el bienestar y las preocupaciones de los residentes del sur de Fresno con respecto a los problemas medioambientales locales.

PRINCIPALES RESULTADOS:

Parte 1: Evaluación de la Salud de la Población

» Los residentes del sur de Fresno tenían una mayor probabilidad de vivir cerca de una calle principal, una ruta de camiones o una autopista.

» Ser expuesto a contaminantes de aire como las $PM_{2.5}$, el ozono y el diésel son asociados con un mayor riesgo de parto prematuro, mortalidad infantil y más visitas de urgencias u hospitalización por asma o enfermedades relacionadas con los vasos sanguíneos del corazón y el cerebro (por ejemplo, infarto de miocardio, accidente cerebrovascular, etc.).

» Las personas embarazadas que vivían entre 1,000 pies de una autopista, 1,000 pies de una ruta de camiones o 300 pies de una carretera principal tenían un riesgo significativamente mayor de sufrir un embarazo adverso, incluso el parto prematuro y la mortalidad infantil.[2]

» Las tasas de nacimientos prematuros, mortalidad infantil y asma eran más altas entre los residentes de los límites de la comunidad del Sur de Fresno en comparación con el resto de la ciudad.

» Incluso con el mismo nivel de ser expuesto a la contaminación del aire, los residentes dentro de los límites de la comunidad del Sur de Fresno y las comunidades de color sufrieron mayores riesgos de salud.

» Los efectos de $PM_{2.5}$ fueron más elevados durante la temporada de frio (noviembre-abril) mientras que los efectos del ozono fueron más elevados durante la temporada de calor (mayo-octubre).

Parte 2: Encuesta Comunitaria del Sur Fresno

» Los residentes dentro de los límites de la comunidad del Sur de Fresno, expresaron un alto nivel de preocupación por la salud ambiental relacionada con las condiciones de las carreteras, la contaminación y el cambio climático.

» La mayoría de los residentes del Sur de Fresno apoyan los esfuerzos locales para alejar los camiones de las zonas residenciales locales.

» Casi la mitad de los residentes (43%) declararon tener al menos un problema de salud crónico, y más de una cuarta parte de las mujeres en edad reproductiva (18-46 años) declararon haber tenido un resultado adverso en el embarazo, como aborto espontáneo (22%), muerte fetal (3%), mortalidad infantil (0.8%) o haber tenido un hijo con un defecto congénito (1.6%).

» La mayoría de los residentes declararon que "a veces", "a menudo" o "siempre" no poder descansar debido a la contaminación de aire (61%) y el ruido del tráfico/camiones (49%). Estos residentes son más probables de tener problemas de salud.

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[2] Estos límites son los que mejor distinguen los riesgos entre los residentes dentro y fuera. Por tanto, nuestros resultados no sugieren que los que viven fuera de esta zona tengan riesgos insignificantes.

» Los que vivían entre 1,000 pies de un ruta de camiones, autopista o carretera principal tenían una mayor prevalencia de problemas de salud crónicos y resultados adversos del embarazo.[3]

RECOMENDACIONES CLAVE:

» El Estudio de Desvió de Camiones del Sur de Fresno debe proponer opciones que minimicen, de la mayor manera posible, las rutas de camiones y el tráfico dentro de 1,000 pies de las zonas residenciales.

» Se debe considerar una zona de mayor protección, dado que los residentes dentro de la comunidad AB617 del Sur de Fresno, y las comunidades de color, corren mayores riesgos de salud por ser expuestos a los mismos niveles de contaminación

» Aplicar estrategias basada en las temporadas específicas para reducir las emisiones de los camiones. Se demostró que la exposición aguda tiene importantes consecuencias para la salud; y mientras que el verano presenta el mayor riesgo de exposición al ozono, el invierno presenta el mayor riesgo de exposición a las partículas $PM_{2.5}$.

» También se recomienda el use de camiones comerciales de cero emisiones para reducir la exposición de la población a la contaminación de aire.

[3] Estos límites son los que mejor distinguen los riesgos entre los residentes dentro y fuera. Por tanto, nuestros resultados no sugieren que los que viven fuera de esta zona tengan riesgos insignificantes.

INTRODUCTION AND BACKGROUND

Air pollutants, including fine particles and ozone, have been consistently linked to many health outcomes across the lifespan, ranging from minor respiratory irritation to cardiorespiratory complications and even premature death.[1-6] Biologic mechanisms linking air pollution to adverse health outcomes include oxidative stress, systemic inflammation, and endocrine disruption.[7,8] Despite a significant body of work, very few studies have comprehensively evaluated the health impacts of air pollution in Central California, an area with significant air pollution levels, marked health disparities, and severely limited access to care.[9,10]

Fresno, home to almost 545,000 residents, is the fifth largest city of California and is located in the San Joaquin Valley (SJV). It is characterized by some of the nation's greatest environmental inequalities. In 2022, Fresno ranked highest for short-term particle pollution, second highest for year-round particle pollution, and fourth highest for ozone pollution in the nation.[11] Reasons contributing to the high pollution levels in the SJV include topography and, more importantly, the numerous pollution sources. The SJV is surrounded by mountain ranges that can trap air pollutants for an extended time. The weather conditions (e.g., heat, sunlight) are conducive to pollution formation and retention. The area also has heavy truck traffic, many diesel-burning locomotives, and other sources of pollution on I-5 and Highway 99 as well as other sources. These sources emit significant amounts of fine particles and precursors to ozone including nitrogen oxides (NO_x) and volatile organic compounds (VOC). These precursors react with heat and sunlight to form harmful ground-level ozone, which often exceeds recommended standards. Although the levels of ozone and fine particles in the SJV have generally declined in recent years, these pollutants remain significant public health concerns.[12] As such, continued efforts to reduce emission and population exposure are critical.

In 2017, the California governor signed Assembly Bill 617, which aims to develop a new community-focused program to more effectively reduce exposure to air pollution and preserve public health. This bill directs the CARB and all local air districts, including the Air District, to take measures to protect communities disproportionally impacted by air pollution.

In 2022, The Air District and the City of Fresno joined forces to undertake the South-Central Fresno AB 617 Community Truck Reroute Study, which will identify, analyze, and evaluate potential strategies that freight-impacted communities might implement to abate truck impacts (e.g., health, pollution, noise, etc.). In the same year, UC Merced was commissioned by the City of Fresno to conduct a Health Impact Assessment (HIA) within the city. The results of the Fresno HIA are intended to inform the ongoing South Fresno Truck Reroute Study.

STUDY OBJECTIVES

The primary objective of the Fresno HIA is to **assess the impact of air pollution (and proximity to truck traffic) on the risk of common health outcomes across the lifespan**. These health outcomes include infant mortality, preterm delivery, asthma, and cardio cerebral vascular events in the city of Fresno from 2009 to 2020. Second, to inform policy and planning efforts, we also calculated the excess number of cases that are attributed to air pollution in the region. Stated differently, these estimates refer to the number of cases that could be prevented if air pollution levels are minimized. Additionally, we also explored how the health impacts of air pollution differ within subgroups of the Fresno population. Third, we conducted **a South Fresno community-based health survey** to understand residents' concerns, health outcomes, and health needs that are relevant to the South Fresno Truck Reroute Study.

The HIA utilizes both large population-based datasets from the Department of Health Care Access and Information (HCAi) and a representative sample community-based survey. The study also makes use of publicly available data. Detailed data sources associated with each study component are described in **Table 1**.

Table 1. Data sources used in the Fresno Health Impact Assessment

Study component	Data sources	Type of Data	Geography	Specificity
Chapter 1: Adverse Pregnancy Outcomes (preterm birth and infant mortality)	California Department of Health Vital Statistics	Birth certificates	City of Fresno	Zip Code
	SJV Air Pollution Control District	$PM_{2.5}$, ozone	City of Fresno	Zip Code
	California Air Resource Board (CARB)	AB 617 community boundaries	South Fresno	N/A
	Fresno GIS Hub	Distance from truck route, major road, freeway	City of Fresno	Geocodable address
	CalEnviroscreen 4.0, California Office of Environmental Health Hazard Assessment (OEHHA)	cumulative traffic, diesel, $PM_{2.5}$, ozone; other neighborhood indicators	City of Fresno	Census Tract boundaries
Chapter 2: Asthma	California Department of Health Care Access and Information	Emergency department visit and hospitalization	City of Fresno	Zip Code
	SJV Air Pollution Control District	$PM_{2.5}$, ozone	City of Fresno	Zip Code
Chapter 3: Cardio cerebral vascular diseases	Department of Health Care Access and Information	Emergency department visit and hospitalization	City of Fresno	Zip Code
	SJV Air Pollution Control District	$PM_{2.5}$, ozone	City of Fresno	Zip Code
Chapter 4: Community-based survey	Primary data collection, UC Merced, Community and Labor Center	Representative community survey	Fresno AB 617 area	Geocodable address
	Fresno GIS Hub	Distance from truck route, major road, freeway	City of Fresno	Geocodable address

This assessment is designed to be consistent with the World Health Organization's general principles of health risk assessment of air pollution,[13] while incorporating important information that is relevant to the city of Fresno.

Objectives are listed below:

1. Determine the impacts of proximity to major road and truck routes on risks of preterm birth and infant mortality in the City of Fresno from 2009 to 2019
2. Determine the impacts of air pollution exposures on risks of preterm birth, infant mortality, childhood asthma, and adult cardiovascular diseases in the City of Fresno from 2011 to 2020
3. Estimate the excess number of preterm births, infant mortality, asthma, and cardiovascular disease cases that were potentially attributed to air pollution exposures
4. Conduct a community-based survey to further understand environmental concerns in South Central Fresno, an area identified by the State under AB 617 to be disproportionately affected by pollution

CHAPTER 1. POLLUTION AND ADVERSE BIRTH OUTCOMES IN FRESNO, CALIFORNIA

1.1 BACKGROUND

Pregnant women and their unborn fetuses are extremely vulnerable to environmental pollution. [14-16] Due to the rapid and complex changes, pregnancy is considered the ultimate stress test.[17,18] During a normal pregnancy, bodily organs and systems change in different ways at different times in a tightly coordinated manner to accommodate the growing fetus.[19] Thus, exposure to hazardous environmental factors during pregnancy result in both immediate and cascading long-term effects, especially for the growing fetus. Meanwhile, the placenta supports exchanges of nutrients, gases, and metabolites while gatekeeping the transfer of harmful pathogens and environmental chemicals to the growing fetus. However, recent studies have shown that fine particles can cross the placental barriers and reach the developing fetus.[20,21] These concerning effects of air pollution on pregnancy merit further attention, especially in regions with high pollution and a high burden of adverse pregnancy outcomes.

Preterm birth (PTB), defined as a birth occurring before 37 weeks of gestation, is a common and serious pregnancy outcome. In 2021, PTB occurred in approximately 9% of all pregnancies in California, but the rate is higher in Fresno, affecting about 11% of pregnancies.[22] In the same year, PTB rates were highest for American Indian/Alaskan Natives (15.2%), followed by Black (14.8%), multi-race (11.3%), Hispanic (10.1%), Asian (9.7), and White (9.3%).[23] PTB is known to be associated with multiple immediate and long-term health complications for affected babies. Because babies need the final weeks in the womb to further develop, PTB results in many problems, including issues related to breathing, temperature control, digestion, and metabolic and immune functions.[24] Due to these health complications, a delivery affected by PTB, on average, costs about four times more than a healthy delivery.[22] More importantly, babies born preterm have a significantly higher risk of developing many health complications later in life, including asthma, obesity, cardiovascular disease, mental health complications, learning disabilities, poorer academic performance, and even cancer.[25-33] Another devastating birth outcome is infant mortality (IM), defined as death occurring to a live birth within the first year of life. Although IM is rarer, occurring at 3.9 per 1,000 live births in 2020 in California, it is a devastating outcome affecting families in unimaginable ways.[34]

Air pollutants, including fine particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) and ozone, have been consistently linked to adverse pregnancy outcomes including pregnancy loss, restricted fetal growth, preterm birth, and infant death[35-41] through biologic mechanisms including oxidative stress, systemic inflammation, and endocrine disruption.[7,8] Studies also suggest that living close to major air pollution sources such as freeway, major roads, and truck routes are also associated with health risks.[42-46]

Despite a significant body of work, no existing studies have evaluated risks of adverse pregnancy outcomes in relation to air pollution exposures in Fresno, an area with significant air pollution, marked health disparities, and severely limited access to care.[9,10]

The aims of Chapter 1 are as follows:

1. Assess the distribution/patterns of PTB and IM in Fresno.
2. Assess the distribution of pollution burden in Fresno.
3. Evaluate the relationship between residential proximity to freeways, major roads, and truck routes and PTB and IM.
4. Evaluate the effects of acute as well as cumulative exposures to air pollution on PTB/IM. Estimate the number of PTB and IM that can be attributed to short-term air pollution.

1.2 METHODS

1.2.1 PARTICIPANTS

We obtained birth certificate data from the California Department of Health Vital Statistics Office for 106,411 babies born in the city of Fresno from 2009-2019. These birth certificates were also deterministically linked to death certificates if a live birth died within one year. Given the fact that multiple gestations (i.e., twins, triplets, etc.) are predisposed to additional risks of preterm birth and infant mortality, we excluded these births from our analysis. The final analyses included 103,566 singleton babies born in the city of Fresno from 2009 to 2019. Our study has been approved by the Institutional Review Boards from the State of California and the University of California, Merced.

1.2.2 EXPOSURE ASSESSMENT

We obtained daily concentration of two common **air pollutants**—fine particulate matter less than 5 microns ($PM_{2.5}$, 24-hr. average) and ozone (maximum 8-hr. average)—from the Air District. These daily concentrations were estimated by the Air District using a regression-based mathematical model with inputs from local air monitors and the Community Multilevel Air Quality (CMAQ) model output from the California Air Resources Board.[47,48] These data were estimated at the zip code level for spatiotemporal linkages to the birth data described above. Second, **major street, freeway and truck route** data were obtained from the Fresno GIS Hub. This dataset provides information on the location, length, and type of road features within the city of Fresno.

We also obtained **census tract characteristics,** including long-term/cumulative exposures to fine particulate matter, ozone, diesel pollution and traffic from CalEnviroScreen 4.0, which was developed by the California Environmental Protection Agency (CalEPA) and its Office of Environmental Health Hazard Assessment (OEHHA).[49] CalEnviroScreen is a mapping tool that analyzes data regarding environmental, health, and socioeconomic conditions to provide a clear picture of cumulative pollution burdens and vulnerabilities across California's census tracts.

In CalEnviroScreen 4.0, we used four cumulative exposures at the census tract level including traffic, diesel particle emission, annual $PM_{2.5}$ concentration, and average amount of daily maximum 8-hour ozone concentration. Traffic was defined in CalEnviroScreen as traffic density in vehicle-kilometers per hour per road length, within 150 meters of the census tract boundary. Diesel particle exposure was measured as diesel emissions from on-road and non-road sources (in $\mu g/m^3$). Ozone was measured as an annual amount of daily maximum 8-hour ozone concentration (in parts per million), and long-term $PM_{2.5}$ exposure was measured as annual mean $PM_{2.5}$ concentrations (in $\mu g/m^3$).

Table 1.1 provides more details about each of the datasets used in the study.

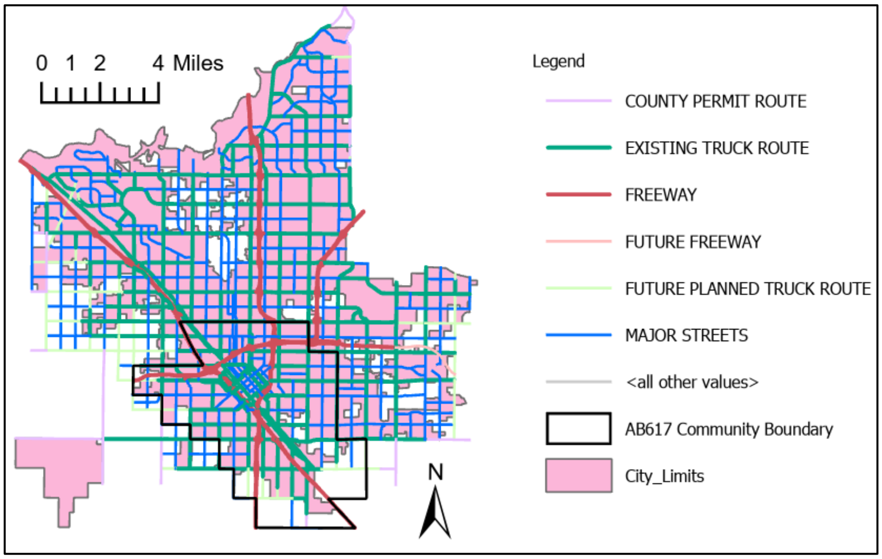
Table 1.1 Data sources

	Data	Sources	URL
Health outcomes	Infant mortality and preterm birth	California Department of Public Health Office of Vital Statistics	https://www.cdph.ca.gov/Programs/CHSI/Pages/Data-and-Statistics-.aspx
Exposures	Daily air pollution exposures	SJV Air District	https://www.valleyair.org/waaqs/
	Neighborhood characteristics including long-term cumulative exposures	California CalEnviroScreen 4.0	https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40
	Distance from truck routes, freeways, and major roads	Fresno GIS Hub	https://gis4u.fresno.gov/downloads/

The addresses of mothers at the time of birth were geocoded and overlaid with the environmental data described above. Daily air pollution exposures were estimated for each pregnant person as the concentration of the zip code within which their residential address fell. Other census tract characteristics were assigned to individuals based on their residential census tract at the time of birth. Distance from freeways, major roads, and existing truck routes were measured using ArcGIS as the

Euclidian distance from each address to the nearest existing road feature. Euclidean distance can be thought of as distance from bird's-eye view. **Figure 1.1** provides a map of road features in the city of Fresno. We note here that "freeway" here includes what locals refer to as "highway" (e.g., Highway 99), as indicated in red. We use this language to be consistent with city documents.

Figure 1.1. Road features in Fresno (source: Fresno GIS Hub)



Note: some features may overlap

1.2.3 OUTCOME ASSESSMENT

The main pregnancy outcomes of interest in this study include preterm birth and infant mortality. Both outcomes were ascertained using birth and death certificates. Specifically, preterm birth (PTB) was defined as a birth occurring before 37 completed weeks of gestation, and infant mortality (IM) was defined as death within the first year of a live birth.

1.2.4 STATISTICAL ANALYSES

Basic statistical tests including t-tests and chi-square tests were used to describe and compare study participant characteristics. Briefly, t-tests and chi-square tests are common statistical methods used to compare two averages (means) and two or more proportions, respectively. We also used basic plots and heat maps to describe the distributions of exposures and outcomes among participants.

To determine the impacts of air pollution and residential proximity to freeways, major streets, and truck routes on adverse pregnancy outcomes, we implemented two different methods. First, we used mixed models to determine the relationship between each pregnancy outcome (PTB and IM) with residential proximity to freeway, major streets, truck routes, diesel emission, traffic, and long-term $PM_{2.5}$ and ozone exposures. In these analyses of cumulative exposures, we compared the risks of PTB and IM between those with varying levels of exposure. We considered potential confounders such as maternal age, race, education, and neighborhood income.

Second, to investigate the impacts of time-varying air pollution on adverse pregnancy outcomes, we used a time-stratified case-crossover analysis.[50] This strategy is a preferred method to examine the short-term relationship between transient exposures (i.e., air pollution) and acute health outcomes (i.e., preterm birth and infant death) due to its ability to allow complete control for non-time-varying confounders.[51] More specifically, in this analysis, we only selected cases who were impacted by the health outcomes of interest. We then compared exposures (i.e., $PM_{2.5}$ and ozone) during a hazard period shortly before the event (preterm birth or infant death) to exposures during control periods during which the event did not happen. The hazard period was defined as the day of event (lag 0) and each of the six days before the event (lags 1-6). Control periods were selected using the time-stratified approach, where controls were selected as the same day of the week within the same month as the case period.[52] For example, if a pregnant person had a preterm birth on Monday, March 12, 2018, then this will be the case period (lag 0). The control periods for this person would be selected as Mondays the 5th, the 19th, and the 26th of the same month of March **(Figure 1.2)**. This approach allows control for days of the week and month and minimizes time-trend bias. Since the comparisons were made within the same person, this approach allows complete control for non-time-varying confounders (or factors that could explain the observed associations). Conditional logistic regression models were used to estimate the risks of adverse pregnancy outcomes associated with 5-unit increase in air pollution exposures.

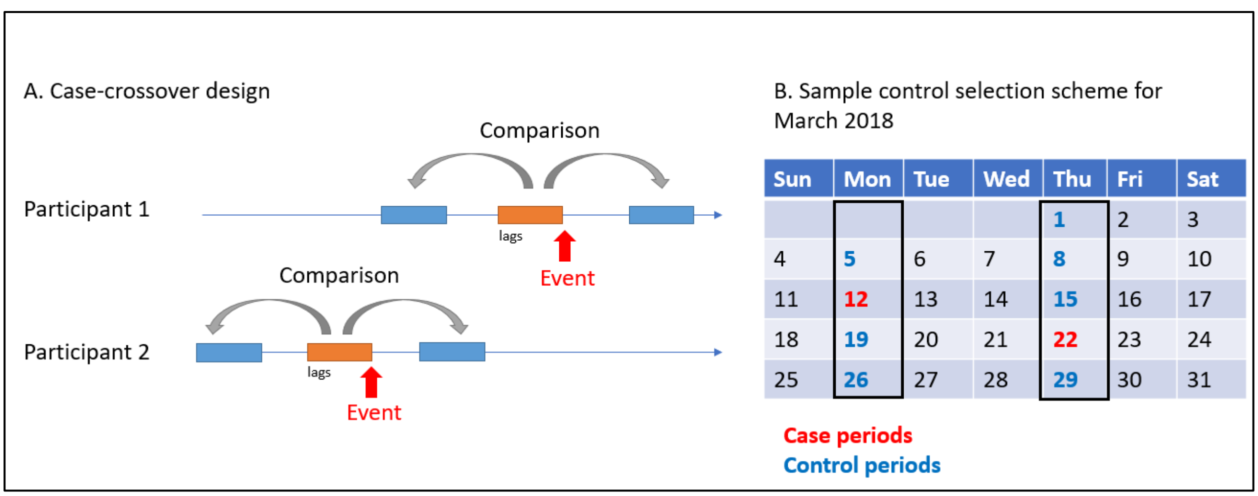
To calculate excess cases of PTB due to air pollution, also known as the attributable risk (AR), we used the formula:

$$AR = I_e - I_u$$

where I_u is the average rate of event in the study population (i.e., background rate), and I_e is the incidence of event among those exposed to the higher pollutants and is calculated as I_u times the odds ratio. I_u represents the background risks (i.e., average in the population) and was calculated as the total number of PTB in the city of Fresno divided by the total annual number of births.

We also stratified our analyses by season (warm: May-October, cold: November – April), maternal characteristics, and residential area (within vs. outside of AB 617 community boundaries) to explore the potential differential effects between different groups. All analyses were performed using SAS 4.0 (Cary, NC), and ArcGIS Pro (Redlands, CA).

Figure 1.2. Case-crossover study design schematic



1.3 RESULTS

1.3.1 DESCRIPTIVE STATISTICS

The analyses included a total of 103,566 singleton live births who were geocoded to the city of Fresno during the study period (2009-2019). The prevalence of PTB and IM among our singleton participants were 8.8 per 100 births and 6.7 per 1,000 live births, respectively (**Table 1.2**). The composition of the study population is presented in the Table under "All". The rates of PTB and IM were higher among mothers with more extreme reproductive ages, lower education, no prenatal care, low/high BMI, more children, and/or no private insurance. Those who smoked during pregnancy or had gestational complications also had higher risk. Mothers who are Black, Hawaiian/Pacific Islander or multi-race and those who lived in poorer neighborhood also had higher PTB rates.

The risks of PTB and IM were also slightly higher among mothers who lived within 1,000 feet of a freeway or truck route. Mothers of babies impacted by PTB and IM were also more likely to live in areas with higher cumulative exposures to traffic and diesel particles (**Table 1.2**).

Table 1.2. Characteristics of singleton live births in Fresno, California, 2009-2019

Characteristics	All (n=103,566) [n (%) or mean (SD)]	Preterm birth (n=9087, 8.8%)	Term birth (n=94479, 91.2%)	Infant mortality (n=698, 0.67%)	No infant mortality (n=102868, 99.3%)
Fetal sex					
Male	52,610 (50.8)	4,937 (9.3)	47,673 (90.6)	370 (0.70)	52,340 (99.3)
Female	50,953 (49.2)	4,184 (8.1)	46,805 (91.8)	325 (0.64)	50,628 (99.3)
Undetermined	3 (0.0)	2 (66.6)	1 (33.3)	3 (100)	0 (0)
Maternal age (years)					
<18	3176 (3.1)	299 (9.4)	2,877 (90.5)	24 (0.76)	3,152 (99.2)
18-24	33220 (32.1)	2,710 (8.1)	30,510 (91.8)	217 (0.65)	33,003 (99.35)
25-29	30437 (29.4)	2,463 (8.0)	27,974 (91.9)	194 (0.64)	30,243 (99.36)
30-34	23416 (22.6)	2,132 (9.1)	21,284 (90.9)	157 (0.67)	23,259 (99.33)
≥35	13315 (12.9)	1,482 (11.1)	11,833 (88.8)	105 (0.79)	13,210 (99.2)
Unknown	2 (0)	1 (50)	1 (50)	1 (50)	1 (50)
Maternal education					
<High School	24,692 (23.8)	2,499 (10.1)	22,193 (89.8)	199 (0.81)	24,493 (99.1)
High School/GED	28,327 (27.4)	2,509 (8.8)	25,818 (91.1)	195 (0.60)	28,132 (99.3)
At least some college	40,946 (39.5)	3,376 (8.2)	37,570 (91.7)	236 (0.58)	40,710 (99.4)
Advanced degree	4,249 (4.1)	266 (6.2)	3,983 (93.7)	20 (0.47)	4,229 (99.5)
Unknown	5,352 (5.2)	437 (8.1)	4,915 (91.8)	48 (0.90)	5,304 (99.1)
Maternal race/ethnicity					
Non-Hispanic White	18,602 (18.0)	1,364 (7.3)	17,238 (92.6)	111 (0.6)	18,491 (99.4)
Non-Hispanic Black	7,450 (7.2)	968 (12.9)	6,482 (87.0)	91 (1.2)	7,359 (98.7)
Hispanic	55,575 (53.7)	4,805 (8.6)	50,770 (91.3)	353 (0.6)	55,223 (99.3)
American Indian/Alaskan Natives	1,047 (1.0)	122 (11.6)	925 (88.3)	2 (0.1)	1,045 (99.8)
Asian	15,555 (15.0)	1,353 (8.7)	14,202 (91.3)	90 (0.5)	15,465 (99.4)
Hawaiian/Pacific Islanders	148 (0.14)	15 (10.1)	133 (89.8)	3 (2.0)	145 (97.9)

Characteristics	All (n=103,566) [n (%) or mean (SD)]	Preterm birth (n=9087, 8.8%)	Term birth (n=94479, 91.2%)	Infant mortality (n=698, 0.67%)	No infant mortality (n=102868, 99.3%)
Others	817 (0.8)	70 (8.5)	747 (91.4)	3 (0.3)	814 (99.6)
Unknown	1,641 (1.6)	117 (7.1)	1,524 (92.8)	14 (0.8)	1,627 (99.1)
Multi-race	2,731 (2.6)	273 (10.0)	2,458 (90.0)	32 (1.1)	2,699 (98.8)
Insurance at delivery					
Not expected to be medically attended	215 (0.2)	29 (13.4)	186 (86.5)	3 (1.4)	212 (98.6)
Public	73,093 (70.6)	6,698 (9.1)	66,395 (90.8)	528 (0.7)	72,565 (99.2)
Private	28,927 (29.9)	2,069 (7.1)	26,858 (92.8)	138 (0.4)	28,789 (99.5)
Self-pay	1,180 (1.1)	273 (23.1)	907 (76.8)	27 (2.2)	1,153 (97.7)
Other	98 (0.1)	9 (9.1)	89 (90.8)	1 (1.0)	97 (98.9)
Unknown	53 (0.1)	9 (16.9)	44 (83.0)	1 (1.8)	52 (98.1)
WIC eligible					
No	28,416 (27.4)	2,570 (9.0)	25,846 (90.9)	229 (0.8)	28,187 (99.1)
Yes	73,613 (71.1)	6,385 (8.6)	67,228 (91.3)	447 (0.6)	73,166 (99.3)
Unknown	1,537 (1.5)	132 (8.5)	1,405 (91.4)	22 (1.4)	1,515 (98.5)
Census tract poverty percentile					
≤25 (least poverty)	6,006 (5.8)	386 (6.43)	5,620 (93.5)	22 (0.3)	5,984 (99.6)
26-50	8,577 (8.3)	637 (7.43)	7,940 (92.5)	32 (0.3)	8,545 (99.6)
51-75	19,751 (19.1)	1,649 (8.3)	18,102 (91.6)	115 (0.6)	19,636 (99.4)
76-100 (most poverty)	69,232 (66.9)	6,415 (9.2)	62,817 (90.7)	529 (0.7)	68,703 (99.2)
Parity					
1	34,162 (33)	2,807 (8.2)	31,355 (91.7)	235 (0.6)	33,927 (99.3)
2	29,160 (28.2)	2,244 (7.7)	26,916 (92.3)	158 (0.5)	29,002 (99.4)
3	19,318 (18.7)	1,625 (8.4)	17,693 (91.5)	115 (0.6)	19,203 (99.4)
4 or more	20,528 (19.8)	2,382 (11.6)	18,146 (88.4)	185 (0.9)	20,343 (99.1)
Unknown	398 (0.4)	29 (7.29)	369 (92.7)	5 (1.2)	393 (98.7)
Pre-pregnancy BMI					
<18.50	2,860 (2.8)	333 (11.6)	2,527 (88.3)	26 (0.9)	2,384 (99.0)
18.50-24.99	37,614 (36.3)	3,059 (8.1)	34,555 (91.8)	208 (0.5)	37,406 (99.4)
25.00-29.00	27,959 (27)	2,267 (8.1)	25,692 (91.8)	165 (0.5)	27,794 (99.4)
>30	30,190 (29.2)	2,849 (9.4)	27,341 (90.5)	244 (0.8)	29,946 (99.1)
Unknown	4,943 (4.8)	579 (11.7)	4,364 (88.2)	55 (1.1)	4,888 (98.8)
Prenatal smoking					
No	98,764 (95.4)	8,587 (8.69)	90,177 (91.31)	638 (0.6)	98,126 (99.3)
Yes	2,199 (2.1)	270 (12.2)	1,929 (87.7)	32 (1.4)	2,167 (98.5)
Unknown	2,603 (2.5)	230 (8.8)	2,373 (91.1)	28 (1.0)	2,575 (98.9)
Gestational complications					
None	66,892 (64.6)	4,070 (6.08)	62,822 (93.92)	263 (0.3)	66,629 (99.6)
Yes	36,667 (35.4)	5,016 (13.6)	31,651 (86.3)	434 (1.1)	36,233 (98.8)
Unknown	7 (0)	1 (14.2)	6 (85.7)	1 (14.2)	6 (85.7)
Prenatal care					
None	900 (0.9)	385 (42.7)	515 (57.2)	23 (2.5)	877 (97.4)
Early	88,291 (85.3)	7,226 (8.1)	81,065 (91.8)	526 (0.6)	87,765 (99.4)
Late	11,087 (10.7)	1,041 (9.3)	10,046 (90.6)	105 (0.9)	10,982 (99.0)

Characteristics	All (n=103,566) [n (%) or mean (SD)]	Preterm birth (n=9087, 8.8%)	Term birth (n=94479, 91.2%)	Infant mortality (n=698, 0.67%)	No infant mortality (n=102868, 99.3%)
Unknown	3,288 (3.2)	435 (13.2)	2,853 (86.7)	44 (1.3)	3,244 (98.6)
Low birthweight					
No	96,651 (93.3)	4,367 (4.5)	92,284 (95.4)	211 (0.2)	96,440 (99.7)
Yes	6,915 (6.7)	4,720 (68.2)	2,195 (31.7)	487 (7.0)	6,428 (92.9)
Season of birth					
Cold (November-April)	50,083 (48.4)	4,575 (8.7)	47,931 (91.2)	372 (0.7)	52,134 (99.2)
Warm (May – October)	53,483 (51.6)	4,512 (8.8)	46,548 (91.1)	326 (0.6)	50,734 (99.3)
Distance from freeway (ft.)					
≤1,000	13,644 (13.2)	1,308 (9.5)	12,336 (90.4)	125 (0.9)	13,519 (99.0)
>1,000	89,922 (86.8)	7,779 (8.6)	82,143 (91.3)	573 (0.6)	89,349 (99.3)
Distance from major roads (ft.)					
≤1,000	63,243 (61.1)	5,532 (8.7)	57,711 (91.2)	414 (0.6)	62,829 (99.3)
>1,000	40,323 (38.9)	3,555 (8.8)	36,768 (91.1)	284 (0.7)	40,039 (99.3)
Distance from truck routes (ft.)					
≤1,000	5959 (57.9)	5,372 (8.9)	54,586 (91.0)	407 (0.6)	59,552 (99.3)
>1,000	43,607 (42.1)	3,715 (8.5)	39,892 (91.4)	291 (0.6)	43,316 (99.3)
Cumulative traffic exposures (percentile)	43.2 (25.6)	43.4 (25.9)	43.2 (25.6)	44.1 (26.6)	43.2 (25.6)
Cumulative diesel PM exposures (percentile)	54.3 (26.5)	55.5 (26.6)	54.1 (26.5)	57.2 (26.9)	54.2 (26.5)
Cumulative $PM_{2.5}$ (percentile)	96.3 (1.4)	96.3 (1.4)	96.2 (1.4)	96.4 (1.4)	96.3 (1.4)
Cumulative ozone (percentile)	83.3 (3.2)	83.2 (3.1)	83.3 (3.2)	83 (3)	83.3 (3.2)

Abbreviations: BMI, body mass index; PM, particulate matter

When aggregated at the zip code levels, the rates of PTB and IM varied spatially across the city of Fresno, with evidence of the highest concentration in the south-central region (**Figure 1.3**). Rates of PTB and IM were consistently higher among those who lived in zip codes within the South Fresno AB 617 Community boundaries compared to the rest of the city during the entire study period (**Figure 1.4**). More specifically, the rates of PTB were 9.7% inside the AB 617 community boundaries and 8.5 for the rest of the city. Similarly, the rates of IM were 8.9 per 1,000 inside and 6.0 per 1,000 outside of the boundaries.

Figure 1.3. Spatial distribution of preterm birth (rates per 100) and infant mortality (rates per 1,000) by zip code in Fresno, California, 2009-2019

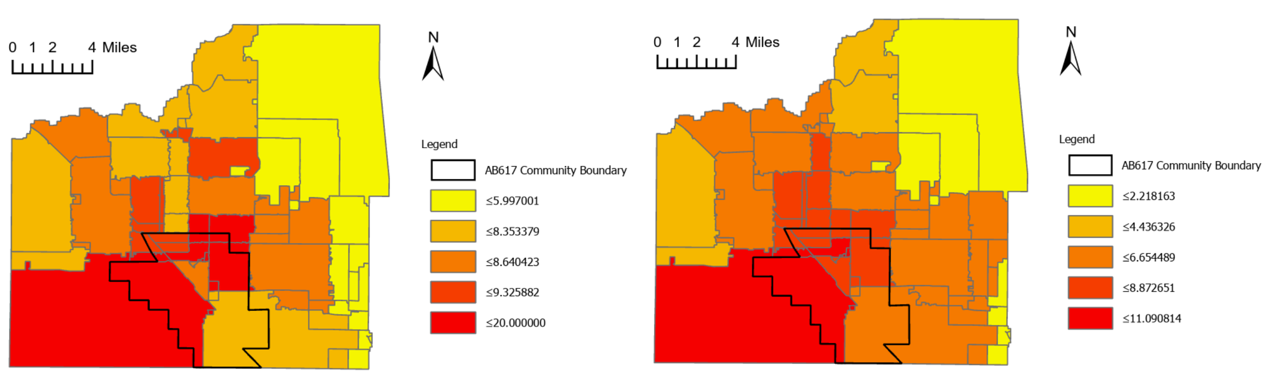
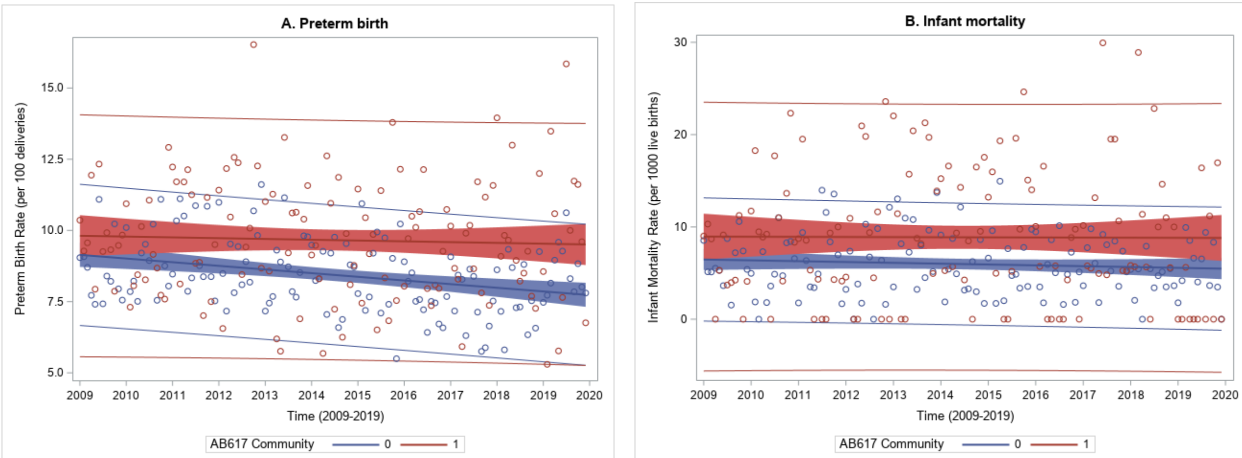


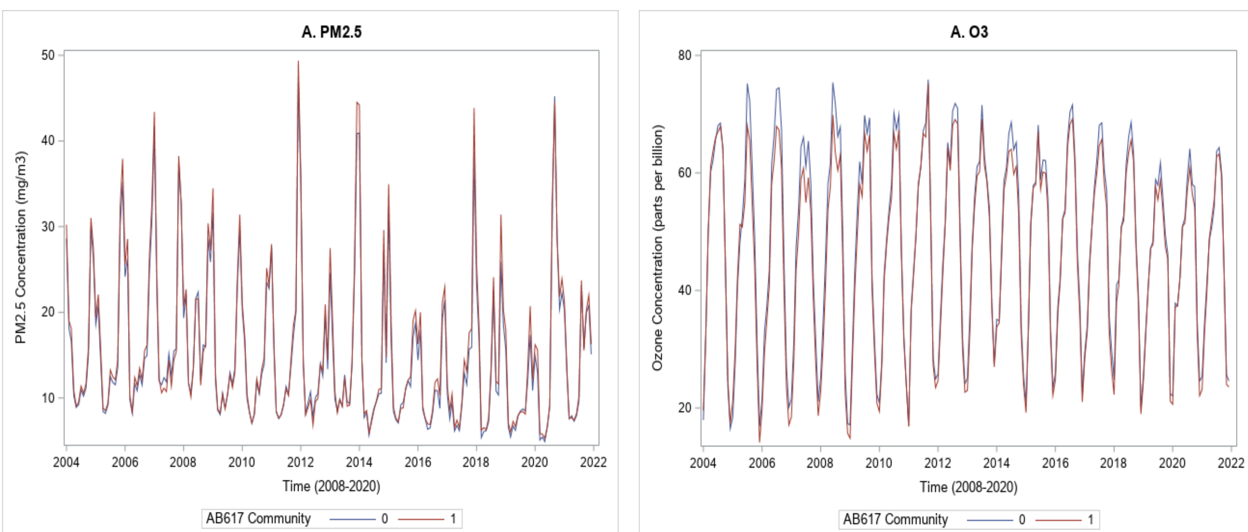
Figure 1.4. Rates of preterm birth (A) and infant mortality (B) by time in Fresno, 2009-2019



The red-shaded region represents the rates within South Fresno and the blue-shaded region represents the rates for the rest of the city.

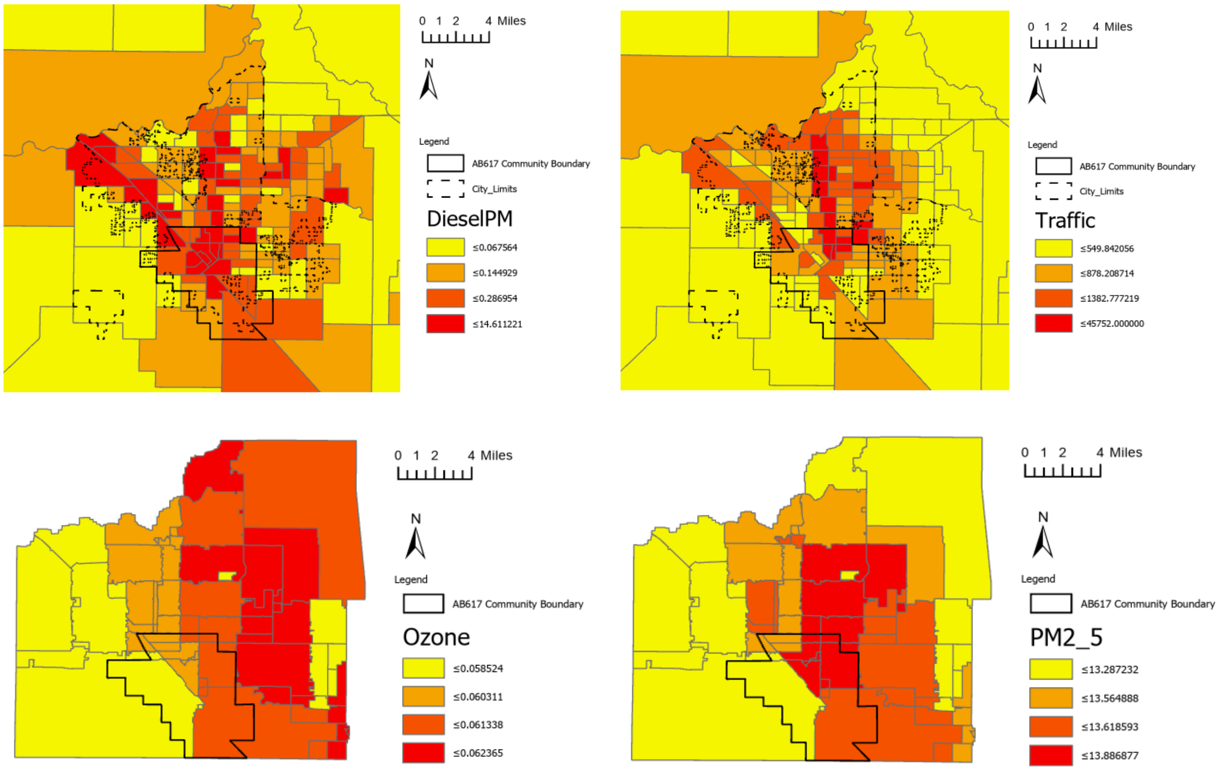
During the study period, daily $PM_{2.5}$ and ozone concentrations varied by season as expected. $PM_{2.5}$ concentrations were higher during the colder months and ozone concentrations were higher during the warmer months. They appeared to be similar within and outside of the South Fresno AB 617 Community boundaries (**Figure 1.5**). Annual average concentrations of $PM_{2.5}$ decreased slightly but concentrations of ozone remained consistent.

Figure 1.5. Temporal distribution of $PM_{2.5}$ and ozone during the study period



Meanwhile, there is spatial variation in cumulative diesel, traffic, $PM_{2.5}$ and ozone levels (**Figure 1.6**). More specifically, diesel particle and traffic exposures were higher in census tracts along freeways and areas with more roads. Cumulative $PM_{2.5}$ and ozone exposures were higher in the western part of the city compared to the rest. Data also show that traffic levels (972.2 vs. 845.7), diesel emissions (0.36 vs. 0.20), and cumulative $PM_{2.5}$ concentrations (13.8 vs. 13.5) were higher in zip codes within the South Fresno AB 617 Community boundaries compared to the rest of the city (**Table 1.3**).

Figure 1.6. Spatial distribution of cumulative air pollution indicators in Fresno (source: CalEnviroScreen 4.0)



Diesel particles are measured as diesel emissions from on-road and non-road sources (ug/m^3); traffic is measured as traffic density in vehicle-kilometers per hour per road length, within 150 meters of the census tract boundary; ozone is measured as annual amount of daily maximum 8-hour ozone concentration (ppm); $PM_{2.5}$ is measured as annual mean $PM_{2.5}$ concentrations (µg/m^3).

Data also suggests that pregnant people in zip codes within the South Fresno AB 617 Community boundaries, on average, were closer to freeways, truck routes, and major streets compared to pregnant people outside of this community (**Table 1.3**).

Table 1.3. Long-term exposures by community boundaries

	Mean (SD)	
Exposures	**Within South Fresno AB 617 Community**	**Outside South Fresno AB 617 Community**
Traffic	972.2 (717.9)	845.7 (452.0)
Diesel particles	0.4 (0.3)	0.2 (0.2)
$PM_{2.5}$	13.8 (0.1)	13.5 (0.3)
Ozone	60.5 (0.5)	60.6 (1.4)
Distance from freeway (feet, mean, SD)	3451.2 (2651.5)	5885.3 (4410.3)
Distance from major road (feet, mean, SD)	970.7 (779.3)	1064.7 (1350.6)
Distance from truck route (feet, mean, SD)	843.3 (702.0)	1266.6 (1624.3)

Diesel particles are measured as diesel emissions from on-road and non-road sources (ug/m^3); traffic is measured as traffic density in vehicle-kilometers per hour per road length, within 150 meters of the census tract boundary; ozone is measured as annual amount of daily maximum 8-hour ozone concentration (ppm); $PM_{2.5}$ is measured as annual mean $PM_{2.5}$ concentrations (ug/m^3).
Abbreviations: PM, particulate matter; SD, standard deviation.

1.3.2 EFFECTS OF PROXIMITY TO FREEWAYS, MAJOR ROADS, AND TRUCK ROUTES

On average, pregnant people who lived closer to freeways, truck routes, or major streets were exposed to higher concentrations of pollutants (**Figure 1.7 – Figure 1.9**). More specifically, the closer pregnant people lived to freeways, the greater the exposures to $PM_{2.5}$, diesel, and traffic they were exposed (**Figure 1.7**). Similarly, people living closer to truck routes (**Figure 1.8**) and major streets (**Figure 1.9**) were exposed to higher $PM_{2.5}$, ozone, diesel emissions, and traffic.

Figure 1.7. Relationship between residential distance to freeways and air pollution exposures

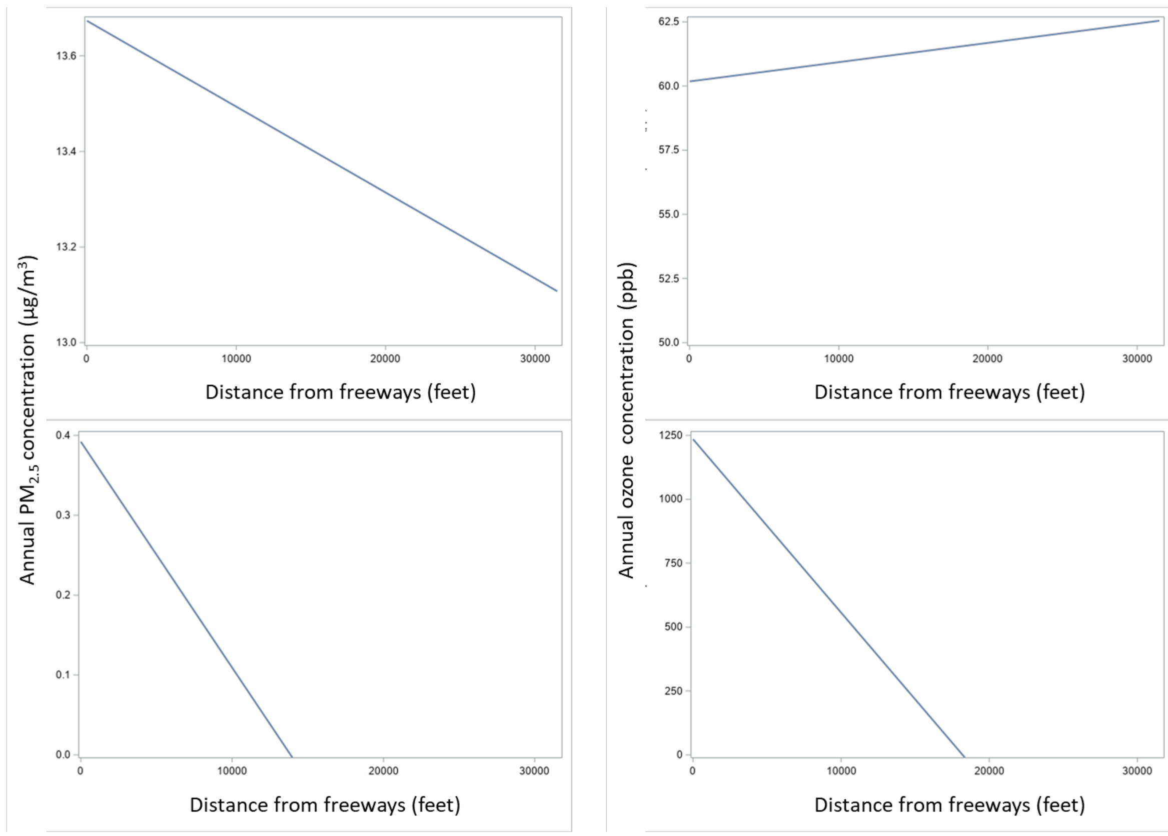


Figure 1.8. Relationship between residential distance to truck routes and air pollution exposures

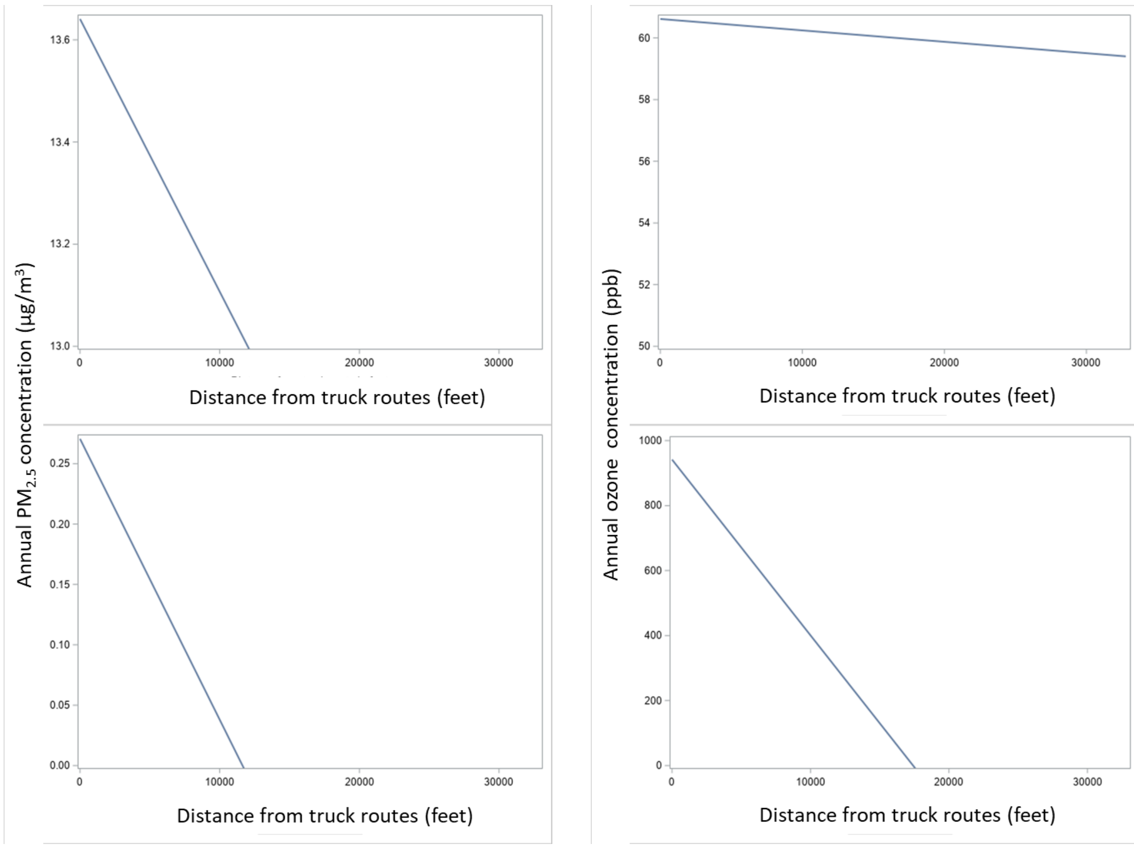
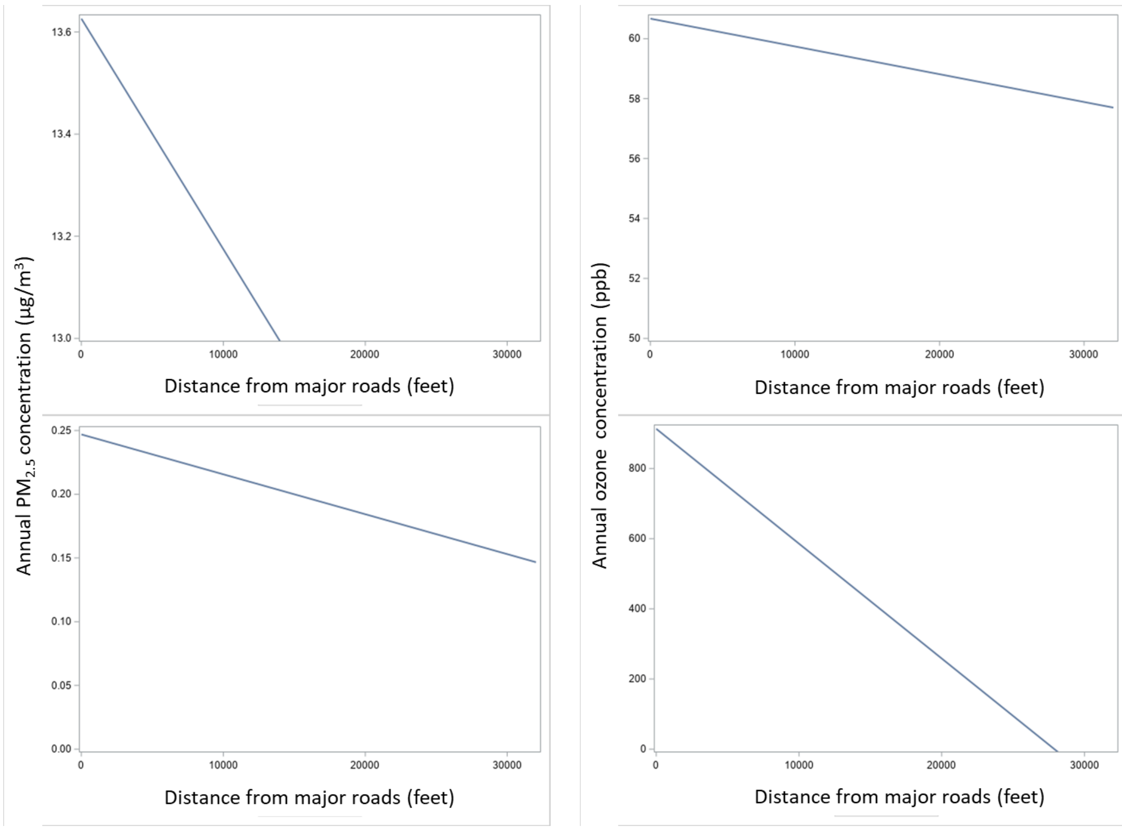
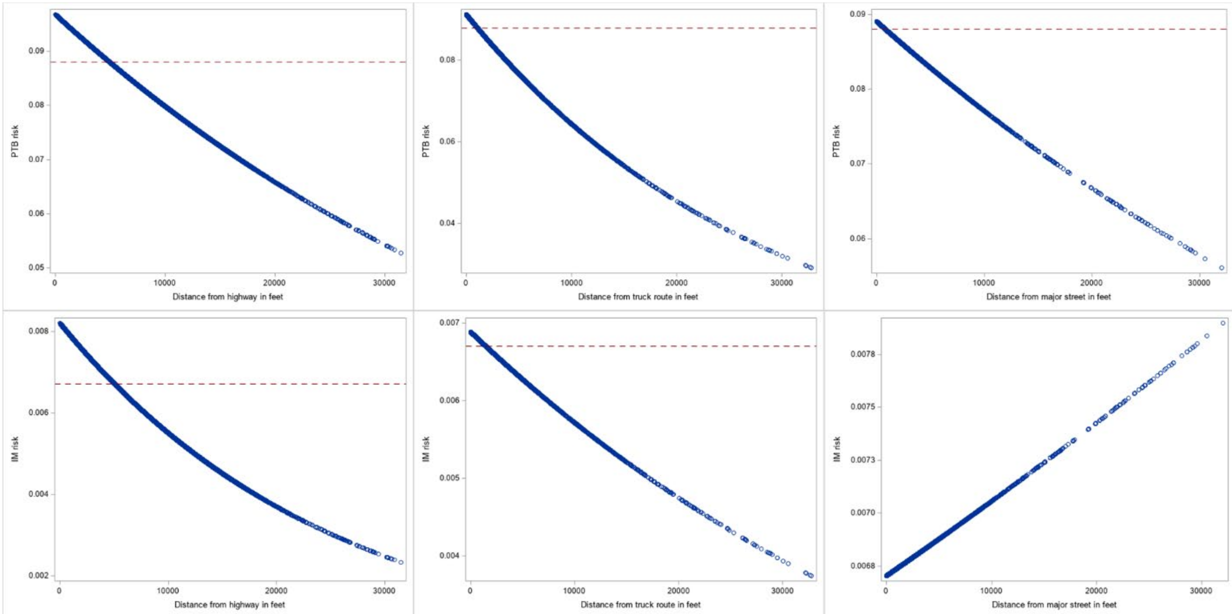


Figure 1.9. Relationship between residential distance to major roads and air pollution exposures



In general, proximity to freeways, truck routes, and major roads were correlated with increased probability of PTB or IM (**Figure 1.10**). More specifically, the predicted risk of both PTB and IM increased as distance from freeways and truck routes decreased. While distance from major streets was negatively correlated with PTB risk, this observation was not seen for IM.

Figure 1.10. Graphical correlation between residential proximity to road sources and adverse pregnancy outcomes



The red dash line represents the average rate in the study population.

Our mixed models suggest that every 500 feet closer to a freeway or major road was associated with a 1% increase in PTB risks. Similarly, 500 feet closer to a truck route was associated with about a 2% increase in PTB risk. Although these estimates are small, the public health impact is substantial given the large population living close to freeways and truck routes (**Table 1.2**). Based on the data above, we also explored the different distance thresholds at which risks of PTB and IM increased substantially. Based on exploratory evidence and the literature, we considered multiple buffers (in feet), including 300, 500, 600, 700, 800, 900, and 1,000 feet.

Compared to those living >1,000 feet from a freeway, those living ≤1,000 feet had 11% increased risk in PTB, and 44% increased risks of IM. These risks remained consistent for smaller buffers. After adjusting for key characteristics including maternal age, race/ethnicity, maternal education, and area level poverty level, the associations remained significant for IM (**Table 1.4**), where infants who lived within 1,000 feet of a freeway had a 23% increased risk of dying within the first year of life.

A similar pattern of association was observed for proximity to truck routes in relation to PTB. More specifically, living within 1,000 feet of a truck route was associated with about 5% increased risk of PTB, and these risks remained consistent for closer buffers. These associations remained elevated after adjusting for covariates, but the estimates were less precise. There appeared to be no association between proximity to truck routes and IM, which could potentially be because of the low number of IM cases.

Those who lived within 300 feet of a major road had about 4-5% increased risk of PTB and IM after adjusting for potential confounders. However, estimates for IM were not precise due to the small number of cases.

We also note that although the 1,000 feet buffer is the proximity that best distinguishes the risks between those inside and outside, we observed that – in most cases – the risk increased as we moved closer to the source. As such, these findings do not suggest that people who live beyond 1,000 feet away from a source are not exposed to risks.

Table 1.4. Associations between proximity to freeways, major roads, and truck routes and perinatal outcomes

	RR (95% CI)			
	Preterm birth Unadjusted	Adjusted[b]	Infant mortality Unadjusted	Adjusted[b]
Freeway (feet)				
Continuous[a]	**1.01 (1.01,1.01)**	1.00 (1,00,1.01)	**1.02 (1.01,1.03)**	1.00 (0.99,1.02)
≤1,000	**1.11 (1.05,1.17)**	1.04 (0.98,1.10)	**1.44 (1.19,1.74)**	**1.23 (1.01,1.50)**
≤900	**1.10 (1.04,1.16)**	1.03 (0.97,1.09)	1.23 (1.00,1.52)	1.05 (0.85,1.30)
≤800	**1.09 (1.02,1.16)**	1.02 (0.96,1.09)	1.20 (0.96,1.50)	1.03 (0.82,1.29)
≤700	**1.08 (1.01,1.16)**	1.01 (0.95,1.09)	1.17 (0.92,1.50)	1.00 (0.78,1.29)
≤600	1.06 (0.98,1.14)	0.99 (0.92,1.07)	1.05 (0.79,1.39)	0.90 (0.67,1.19)
≤500	**1.09 (1.00,1.18)**	1.02 (0.94,1.11)	1.11 (0.81,1.51)	0.95 (0.69,1.30)
≤300	1.05 (0.93,1.19)	0.99 (0.87,1.12)	1.03 (0.64,1.64)	0.89 (0.56,1.42)
Truck routes (feet)				
Continuous[a]	**1.02 (1.01,1.03)**	**1.01 (1.00,1.02)**	1.01 (0.98,1.04)	0.99 (0.97,1.02)
≤1,000	**1.05 (1.01,1.09)**	1.01 (0.97,1.05)	1.02 (0.88,1.18)	0.92 (0.79,1.07)
≤900	**1.07 (1.03,1.11)**	1.04 (0.99,1.08)	1.02 (0.88,1.18)	0.94 (0.81,1.09)
≤800	**1.07 (1.03,1.12)**	1.03 (0.99,1.08)	1.03 (0.89,1.20)	0.95 (0.82,1.11)
≤700	**1.07 (1.03,1.11)**	1.04 (0.99,1.08)	1.05 (0.91,1.22)	0.98 (0.84,1.14)
≤600	**1.07 (1.03,1.12)**	1.03 (0.99,1.08)	1.10 (0.95,1.28)	1.02 (0.88,1.19)
≤500	**1.07 (1.03,1.12)**	1.04 (0.99,1.08)	1.07 (0.92,1.26)	1.00 (0.85,1.18)
≤300	**1.07 (1.02,1.13)**	1.04 (0.99,1.08)	0.99 (0.81,1.21)	0.94 (0.77,1.15)
Major road (feet)				
Continuous[a]	**1.01 (1.00,1.02)**	**1.01 (1.00,1.02)**	1.00 (0.97,1.03)	0.99 (0.97,1.02)
≤1,000	0.99 (0.95,1.03)	0.99 (0.95,1.03)	0.93 (0.80,1.08)	0.93 (0.80,1.08)
≤900	1.01 (0.97,1.05)	1.01 (0.97,1.05)	0.95 (0.82,1.10)	0.95 (0.82,1.10)
≤800	1.00 (0.96,1.04)	1.00 (0.96,1.04)	0.95 (0.82,1.10)	0.95 (0.82,1.10)
≤700	1.01 (0.97,1.05)	1.00 (0.96,1.04)	0.98 (0.84,1.14)	0.97 (0.84,1.13)
≤600	1.03 (0.98,1.07)	1.02 (0.98,1.06)	0.97 (0.84,1.13)	0.96 (0.82,1.11)
≤500	1.03 (0.99,1.08)	1.03 (0.98,1.07)	0.97 (0.83,1.14)	0.95 (0.82,1.12)
≤300	**1.06 (1.01,1.11)**	**1.05 (1.00,1.11)**	1.06 (0.88,1.27)	1.04 (0.86,1.25)

[a] Estimate is for each 500 feet closer to each feature; [b] Models adjusted for maternal age, race/ethnicity, maternal education, area level poverty level
Boldface font indicates statistical significance at p<0.05
Abbreviations: RR, relative risk; CI, confidence intervals.

When stratified by AB 617 community status, we observed that the effects of proximity to truck routes on PTB and major streets on IM were considerably higher within the AB 617 community boundaries. On the other hand, the effects of proximity to freeways were stronger outside the boundaries. Meanwhile, no racial/ethnic differences were detected.

1.3.3 EFFECTS OF CUMULATIVE EXPOSURES TO DIESEL, TRAFFIC, AND AIR POLLUTION

Cumulative (i.e., long-term) exposures to $PM_{2.5}$ and diesel particulate matter were positively associated with risks of both PTB and IM (**Table 1.5**). For each unit increase in cumulative $PM_{2.5}$ exposures, the risks of PTB and IM increased by 26% and 37%, respectively. Similarly, for every unit increase in diesel exposure, risks of PTB and IM increased by 21% and 70%, respectively.

Table 1.5. Associations between cumulative exposures and birth outcomes

	RR (95% CI)	
	Preterm birth	Infant mortality
$PM_{2.5}$	**1.26 (1.14, 1.40)**	**1.37 (1.01, 1.85)**
Ozone	0.99 (0.96, 1.01)	0.94 (0.88, 1.01)
Diesel PM	**1.21 (1.08, 1.35)**	**1.70 (1.26, 2.29)**
Traffic[a]	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)

[a]Traffic density in vehicle-kilometers per hour per road length, within 150 meters of the census tract boundary. Bolded estimates indicate statistical significance at $p<0.05$.
Abbreviations: PM, particulate matter; RR, relative risk; CI, confidence intervals.

In further analyses, we noted that the impacts of cumulative exposures on IM were different across race/ethnicity. More specifically, we observed that American Indian/Alaskan Native communities are more impacted by cumulative exposures compared to other groups. The magnitudes of associations also suggest that Black pregnant people may be more susceptible to $PM_{2.5}$ and Asian/Pacific Islander pregnant people may be more susceptible to diesel. However, due to the low number of IM, our estimates were not precise (**Table 1.6**).

Table 1.6. Associations between chronic exposures and infant mortality by race/ethnicity

Race/ethnicity	**RR (95% CI)**			
	$PM_{2.5}$	Ozone	Diesel	Traffic
White	0.84 (0.67, 1.05)	0.98 (0.94, 1.03)	1.05 (0.78, 1.42)	0.95 (0.84, 1.08)
Black	1.24 (0.90, 1.70)	1.01 (0.95, 1.08)	0.97 (0.75, 1.24)	0.98 (0.87, 1.11)
Hispanic	1.06 (0.94, 1.19)	0.99 (0.97, 1.02)	0.96 (0.86, 1.07)	0.95 (0.90, 1.00)
American Indian/Alaskan Natives	1.68 (0.70, 4.06)	**1.19 (1.01, 1.40)**	1.91 (0.97, 3.77)	1.30 (0.97, 1.73)
Asians/Pacific Islanders	0.93 (0.75, 1.17)	0.98 (0.94, 1.02)	1.17 (0.91, 1.50)	1.03 (0.93, 1.15)

Models adjusted for maternal age, race/ethnicity, maternal education, area level poverty level. Bolded estimates indicate statistical significance at $p<0.05$.
Abbreviations: PM, particulate matter; RR, relative risk; CI, confidence intervals.

1.3.4 ACUTE EXPOSURES TO $PM_{2.5}$ AND OZONE

$PM_{2.5}$ exposures during the prior week were associated with the onset of IM (**Table 1.7**). For example, for every 5 $\mu g/m^3$ increase in $PM_{2.5}$, the risks of IM increased by approximately 6% within three days, and these risks attenuated but continued until about 5 days after exposure.

When analyses were separated by season, the effects of $PM_{2.5}$ on IM remained consistent and appeared to be more prominent during the cold season when the level was the highest. During the warm season where its concentration was the highest, ozone exposure during the prior week was also associated with PTB risks. Each 5-unit increase in exposure was associated with approximately 3% increase in risk within a 7-day window.

Table 1.7. Associations between acute air pollution and adverse perinatal outcomes

Pollutants	OR (95% CI)	
	Preterm birth	Infant mortality
$PM_{2.5}$		
Lag 0	1.000 (0.995,1.005)	**1.061 (1.025,1.099)**
Lag 1	1.000 (0.995,1.005)	**1.061 (1.025,1.099)**
Lag 2	0.990 (0.985,1.005)	**1.056 (1.020,1.093)**
Lag 3	0.995 (0.985,1.005)	**1.046 (1.005,1.083)**
Lag 4	0.995 (0.985,1.005)	**1.035 (1.000,1.077)**
Lag 5	1.000 (0.990,1.010)	**1.035 (1.000,1.077)**
Lag 6	1.000 (0.990,1.010)	1.030 (0.990,1.067)
Ozone		
Lag 0	1.000 (0.990,1.005)	0.990 (0.961,1.020)
Lag 1	1.000 (0.990,1.005)	0.985 (0.956,1.015)
Lag 2	1.000 (0.990,1.005)	0.985 (0.956,1.015)
Lag 3	1.000 (0.990,1.005)	0.980 (0.951,1.010)
Lag 4	1.000 (0.995,1.010)	0.975 (0.946,1.005)
Lag 5	1.005 (0.995,1.010)	0.980 (0.951,1.010)
Lag 6	1.005 (0.995,1.010)	0.980 (0.951,1.010)
Cold-season $PM_{2.5}$ (November-April)		
Lag 0	1.010 (1.000,1.020)	**1.067 (1.025,1.104)**
Lag 1	1.010 (1.000,1.020)	**1.061 (1.025,1.104)**
Lag 2	1.005 (0.995,1.020)	**1.061 (1.025,1.104)**
Lag 3	1.005 (0.995,1.015)	**1.046 (1.010,1.088)**
Lag 4	1.005 (0.995,1.015)	**1.041 (1.000,1.083)**
Lag 5	1.010 (1.000,1.020)	**1.041 (1.000,1.083)**
Lag 6	1.010 (1.000,1.020)	1.030 (0.990,1.072)
Warm season ozone (May-October)		
Lag 0	**1.030 (1.020,1.041)**	1.010 (0.975,1.046)
Lag 1	**1.030 (1.020,1.041)**	1.010 (0.975,1.046)
Lag 2	**1.030 (1.020,1.041)**	1.010 (0.975,1.041)
Lag 3	**1.030 (1.020,1.041)**	1.000 (0.965,1.035)
Lag 4	**1.030 (1.020,1.041)**	1.000 (0.965,1.030)
Lag 5	**1.030 (1.025,1.041)**	1.000 (0.965,1.035)
Lag 6	**1.035 (1.025,1.041)**	1.000 (0.970,1.035)

OR (odds ratios) were obtained for each 5-unit increase in exposure, and were adjusted for individual characteristics by design, temperature, and humidity. Lag can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc. Bolded estimates indicate statistical significance at $p<0.05$.

During the study period, acute exposures to ozone may have been responsible for about 3 additional cases of PTB per 1,000 Fresno births (**Table 1.8**). With approximately 13,500 annual births in Fresno, this is equivalent to about 40 additional cases per year during the study period. Given a PTB delivery costs on average about 5 times as much as an unaffected birth, these excess cases have important implications, not only financially but also medically, given the known serious short- and long-term effects of PTB. **Table 1.8** also shows that $PM_{2.5}$ exposures were potentially responsible for up to 6 additional cases of infant mortality per year.

Table 1.8. Excess cases of PTB and IM in relation to pollution exposure

	Ozone and PTB		**$PM_{2.5}$ and IM**	
	Excess cases per 1,000 births (95% CI)	Excess cases per year[a]	Excess cases per 1,000 births (95% CI)	Excess cases per year[a]
Lag 0	2.67 (1.77,3.57)	36.00 (23.90,48.20)	4.12 (1.69,6.61)	5.60 (2.30,8.90)
Lag 1	2.67 (1.77,3.57)	36.00 (23.90,48.20)	4.12 (1.69,6.61)	5.60 (2.30,8.90)
Lag 2	2.67 (1.77,3.57)	36.00 (23.90,48.20)	3.77 (1.35,6.25)	5.10 (1.80,8.40)
Lag 3	2.67 (1.77,3.57)	36.00 (23.90,48.20)	3.07 (0.34,5.53)	4.10 (0.50,7.50)
Lag 4	2.67 (1.77,3.57)	36.00 (23.90,48.20)	2.38 (0.00,5.18)	3.20 (0.00,7.00)
Lag 5	2.67 (2.22,3.57)	36.00 (29.90,48.20)	2.38 (0.00,5.18)	3.20 (0.00,7.00)
Lag 6	3.12 (2.22,3.57)	42.10 (29.90,48.20)	2.03 (-0.67,4.47)	2.70 (-0.90,6.00)

[a]Fresno has about 13,500 live births per year.
Abbreviations: PTB, preterm birth; $PM_{2.5}$, particulate matter <2.5 microns; IM, infant mortality

1.4 SUMMARY

The research in this chapter suggests that proximity to traffic exposes residents to greater amounts of pollution and, in turn, greater health risks, and that this was true for South Fresno residents living in the AB 617 area—particularly for those from communities of color. Using a birth cohort of all babies born in the city of Fresno from 2009 to 2019, we observed the following key findings:

1. Residential proximity to freeways, truck routes, and major streets were positively associated with the risk of PTB and IM. People who lived within 1,000 feet from a freeway, 1,000 feet from a truck route, or 300 feet from a major road experienced higher risk of pregnancy outcomes.
2. PTB and IM rates were higher in zip codes within the South Fresno AB 617 community boundaries compared to the rest of the city.
3. On average, pregnant people within the South Fresno AB 617 community boundaries had higher long-term exposures to traffic and diesel emissions and lived in closer proximity to pollution sources such as freeways, truck routes, and major streets.
4. Cumulative exposures to $PM_{2.5}$ and diesel PM were more pronounced among pregnant people identifying with communities of color.
5. Acute exposures to ozone and $PM_{2.5}$ were positively associated with PTB and IM. These pollutants were potentially responsible for a significant number of annual excess cases of PTB and IM in Fresno

Although there are few existing studies in Fresno for comparison, our findings are consistent with the literature pertaining to the impacts of pollution on PTB. A recent California statewide study suggested that higher mean levels of $PM_{2.5}$ and diesel particles were associated with higher PTB risks.[53] Like ours, this study also did not find consistent association between proximity to major roads with PTB. Our study is novel, as we additionally evaluated proximity to freeways and truck routes, both of which are major sources of pollution. These findings are consistent with existing knowledge about the higher exposures among people living near freeways and truck routes and their negative impacts on other health outcomes.[54-56]

Our findings are also consistent with a recent analysis on the acute impacts of $PM_{2.5}$ and ozone on PTB in the SJV.[57] This study shows season-specific impacts where ozone was positively associated with PTB in the summer and $PM_{2.5}$ in the winter season. These observations are consistent with the known seasonal variability of the two pollutants, where ozone is much higher in the warm season due to the abundance of sunlight and heat, and $PM_{2.5}$ is higher in the colder season due to temperature inversion.

This study also has had the notable merit of being the first study in the area to evaluate the impacts of proximity to freeways and truck routes. The modelled air pollution data by the Air District has been validated and shows high accuracy.[58] These data are also used for air pollution forecasts and policy decisions in the area. Thus, findings will have direct implications for policy decision. Lastly, the case-crossover nature of our analyses eliminates confounding, which ensures that the effects of air pollution on PTB are unlikely driven by other characteristics.

In summary, our findings generally suggest that living in areas with more pollution sources and pollution concentration (both long-term and short-term) exposes people to significant risks of developing adverse pregnancy outcomes. With evidence of heightened concerns within our AB 617 community boundaries, and communities of color, we recommend future policies take these risks into account and prioritize efforts to reduce pollution emission overall, but especially in highly impacted areas.

1.5 RECOMMENDATIONS

With respect to the Fresno Truck Reroute Study, we specifically recommend:

1. Developing truck routes outside of a 1,000-foot buffer around residential areas. Where appropriate, a bigger buffer could also be used, especially in areas with more vulnerable populations.
2. Planning future truck routes to be at least 1,000 feet from areas where people live, work and play. It would be prudent to avoid truck routes near locations where vulnerable populations are located, such as schools, daycare, and hospitals.
3. Due to the fact that there is seasonal variation in health effects, creative strategies to address seasonal changes may be helpful. For example, seasonal truck regulation may be considered.
4. We also recommend the use of zero-emission commercial trucks when possible to minimize population exposure

CHAPTER 2. AIR POLLUTION AND ASTHMA IN FRESNO, CALIFORNIA

2.1 BACKGROUND

Asthma is a common but serious respiratory illness in California, occurring to about 8.8% of the population in 2021.[59] For the Fresno population, the prevalence of asthma is about 12.8%.[60] Asthma can cause morbidity, sleep disturbance, loss of productivity (e.g., school, work), and reduced quality of life. If unmanaged, asthma can also lead to severe morbidity, hospitalization, and even death.

Studies around the world have linked air pollution to asthma risk with well-established biologic mechanisms.[61,62] However, very few studies have assessed impacts of air pollution on asthma in the San Joaquin Valley (much less Fresno), an area with known concerns related to pollution and heightened asthma risks.

The purpose of this analysis is to estimate the effects of air pollution on asthma among Fresno residents, with regard to major roads, truck routes, and freeways. In addition, we estimated the amount of asthma that could have been prevented by a given decline in localized air pollution.

2.2 METHODS

2.2.1 DATA AND PARTICIPANTS

In this chapter, we examine California Department of Health Care Access and Information (HCAi) Emergency Department (ED) visits and Patient Discharge Data (PDD) between the years 2011 and 2020.[63] These are the latest available data. ED datasets consist of demographic, clinical, and facility information of all emergency department face-to-face encounters with a healthcare provider in California hospitals licensed to provide emergency medical services. Meanwhile, the PDD dataset consists of records for each inpatient discharge from any California-licensed hospital. Licensed hospitals can include general acute care, acute psychiatric care, chemical dependency recovery facilities, and psychiatric health facilities.

For this study, we only selected ED visits and hospitalization from Fresno zip codes. We further restricted the datasets to ED visits and inpatient visits for those with asthma as the primary diagnosis. We also note that due to the lack of personally identifiable information, we cannot follow individuals longitudinally and we therefore have to treat each ED visit or hospitalization as an independent event. We note that people visit the ED and end up being admitted, they only show up under the hospitalization data. In other words, no person would be counted twice for the same encounter.

2.2.2 EXPOSURE ASSESSMENT

We estimated daily exposures to $PM_{2.5}$ and ozone using a similar approach described in **Chapter 1, Section 1.2.2**. Briefly, we obtained daily concentration of two common **air pollutants**, fine particulate matter less than 5 microns ($PM_{2.5}$, 24-hr. average $PM_{2.5}$) and ozone (maximum 8-hr. average), from the Air District. These daily concentrations were estimated by the Air District using a regression-based mathematical model with inputs from local air monitors and the Community Multilevel Air Quality (CMAQ) model output from the California Air Resources Board.[47,48] These data were estimated at the zip code level for spatiotemporal linkages to the health data. Participants were then spatiotemporally linked to daily air pollution data based on their residential zip code at the time of event. We specifically focused on acute air pollution exposure and its effects within seven days following prior knowledge in the field.

Due to the lack of residential addresses from HCAi datasets, we were unable to geocode participants for detailed spatial analyses more granular than the zip code level (such as those in Chapter 1).

2.2.3 OUTCOME ASSESSMENT

We utilized the 9th and 10th version of the International Classification of Disease codes with clinical modification (ICD-9-CM and ICD-10-CM) to identify asthma ED visits and hospitalizations. More specifically, for data prior to 2015, we identified asthma cases as those who had an ED visit or hospitalization with an ICD-9-CM code starting with 493 as the principal diagnosis code. In 2015 and later years, we used ICD-10-CM code J45. To ensure that we capture cases more accurately, we used both ICD-9 and ICD-10 codes in the transition year 2015.

2.2.4 STATISTICAL ANALYSES

To determine the impacts of air pollution on asthma in Fresno, we employed the time-stratified case-crossover analysis to minimize confounding by factors that can also explain risks of asthma. A detailed description of this method is described in section **Chapter 1, section 1.2.4** above. Briefly, in this analysis, we only selected cases that were impacted by asthma. We then compared exposures (i.e., $PM_{2.5}$ and ozone) during a hazard period shortly before the event to exposures during control periods during which the event did not happen. The hazard period was defined as the day of the event (lag 0) and each of the six days before the event (lags 1-6). Control periods were selected using the time-stratified approach, where controls were selected as the same day of the week within the same month as the case period.[52] For example, if someone visited the ED or got hospitalized because of asthma on Monday, March 12, 2018, then this will be the case period (lag 0). Their control period will be selected as Mondays the 5th, the 19th, and the 26th of the same month of March **(Figure 1.2)**. This approach allows control for days of the week and month and minimizes time-trend bias. Since the comparisons were made for the same person, this approach allows complete control for non-time-varying confounders (or factors that could explain the observed associations). Conditional logistic regression models were used to estimate the risks of asthma associated with a 5-unit increase in air pollution exposures. We found meaningful seasonal differences and presented results by season (cold: November – April, warm: May-October). We additionally explored effects by AB 617 residence status and race/ethnicity.

We calculated the access number of asthma ED visits and hospitalizations due to pollution, also known as the attributable risk (AR), using the following formula:

$$AR = I_e - I_u$$

where I_u is background rate of event in the population, and I_e is the incidence of events among those exposed to the higher pollutants and is calculated as I_u times the odds ratio. I_u was calculated as the average annual number of events in the city of Fresno divided by the total population estimated by the 2020 Census (n=545,567).[64]

All analyses were completed in ArcGIS Pro (Redlands, CA), SAS 9.2 (Cary, NC) and Microsoft Excel (Redmond, WA).

2.3 RESULTS

2.3.1 DESCRIPTIVE STATISTICS

The analysis included 45,455 asthma ED visits and 7,296 inpatient hospitalizations among participants in Fresno zip codes (**Table 2.1**).

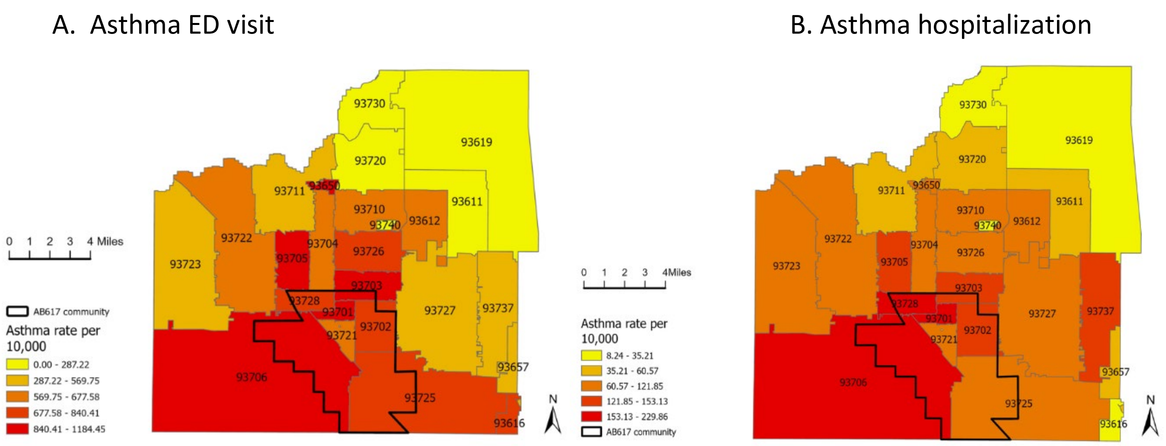
Table 2.1. Characteristics of emergency department visits and hospitalizations related to asthma in Fresno, 2011-2020

Characteristics	Asthma ED visits n= 45455	Asthma hospitalization n= 7479
Age categories (in years)		
0-4	9805 (21.6)	2008 (26.8)
5-17	14374 (31.6)	1843 (24.6)
18-64	19004 (41.8)	2529 (33.8)
65+	2272 (5.0)	1099 (14.6)
Sex		
Female	22674 (49.9)	3735 (49.9)
Male	22781 (50.1)	3744 (50.0)
Race/ethnicity		
Non-Hispanic White	11825 (26.0)	1878 (25.1)
Non-Hispanic Black	5525 (12.1)	1431 (19.1)
Hispanic	25453 (56.0)	2667 (35.6)
Asian/Pacific Islander	1332 (2.9)	489 (6.5)
American Indian/Alaskan Natives	90 (0.2)	17 (0.2)
Other	784 (1.7)	107 (1.4)
Unknown	446 (0.9)	890(11.9)
Principal language		
English	40375 (88.8)	6573 (87.8)
Spanish	4725 (10.4)	621 (8.3)
Other	355 (0.8)	285 (3.8)
Expected source of payment		
Medicare	2034 (4.5)	1370 (18.3)
Medi-Cal	31118 (68.5)	4566 (61.0)
Private	8210 (18.1)	1037 (13.8)
Self-pay	2944 (6.5)	210 (2.6)
Other	1148 (2.5)	304 (4.0)
Unknown	1 (0.00)	1 (0.0)
Season of service		
Warm (May – October)	18879 (41.5)	2971 (39.7)
Cold (November – April)	26576 (58.5)	4508 (60.2)
Year of service		
2011	4637 (10.2)	950 (12.7)
2012	4700 (10.3)	1103 (14.7)
2013	4842 (10.7)	962 (12.9)
2014	5009 (11.0)	999 (13.3)
2015	3983 (8.8)	704 (9.4)
2016	4787 (10.5)	660 (8.8)
2017	5529 (12.2)	615 (8.2)
2018	4885 (10.8)	634 (8.4)
2019	4605 (10.1)	533 (7.1)
2020	2478 (5.5)	311 (4.1)

Abbreviations: ED, emergency department

Cumulative rates of asthma ED visits and hospitalizations across Fresno were observed during the study period, and incidents of asthma appeared to be higher in the south-central region compared to the rest of the city (**Figure 2.1**).

Figure 2.1. Rates of asthma ED visits (A) and hospitalization (B) in Fresno, 2011-2020



Note: Rates were obtained by dividing the total number of asthma ED visits or inpatient hospitalizations by the population size for each zip code from the 2020 census. Abbreviations: ED, emergency department.

Table 2.2. Rates of asthma ED visits within and outside of the South Fresno community boundaries

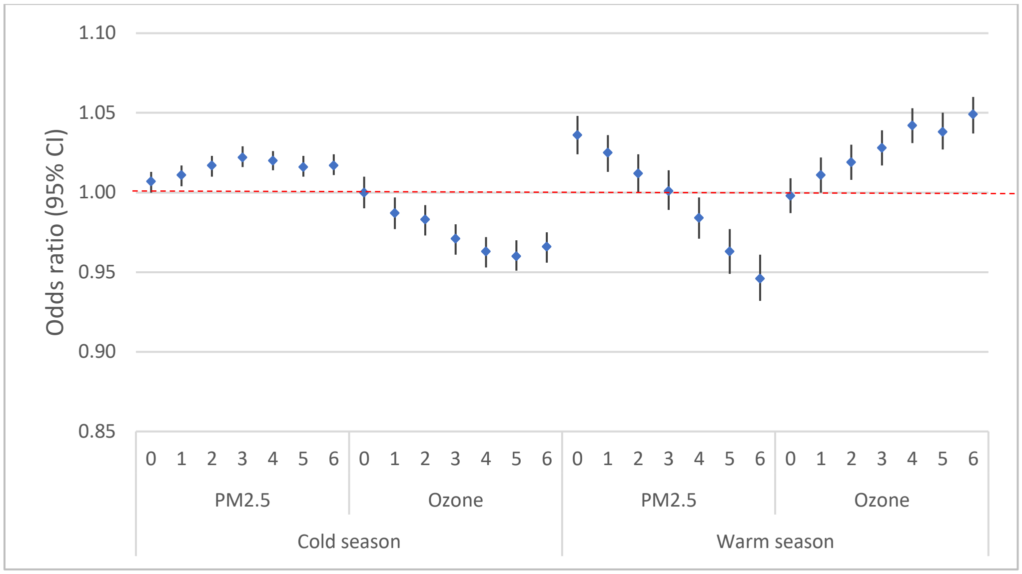
	Rates per 10,000 population (10 years)	
	Within boundaries	Outside boundaries
Asthma ED visits	870.06	521.01
Asthma hospitalization	156.41	78.44

Abbreviations: ED, emergency department.

2.3.2 IMPACTS OF AIR POLLUTION ON ASTHMA

Our case-crossover analyses suggest that exposures to both $PM_{2.5}$ and ozone increased the risk of asthma ED visits, and these effects were season-specific (**Figure 2.2, Figure 2.3, Table 2.3**). During the cold season, a 5-unit increase in $PM_{2.5}$ exposure was associated with approximately a 2% increased risk of having an asthma ED visit 2-6 days later. During the warm season, a 5-unit increase in $PM_{2.5}$ exposures was associated with a 3-4% increased risk of an ED visit within one day of exposure, suggesting more immediate effects when the temperature is hotter (**Figure 2.2**). Ozone appears to only have adverse impacts during the warm season, when its concentration is the highest. Its effects were more pronounced after one day and up to 6 days after exposures. A 5-unit increase in ozone exposure was associated with a 2-5% increased risk of having an asthma ED visit within 1-6 days.

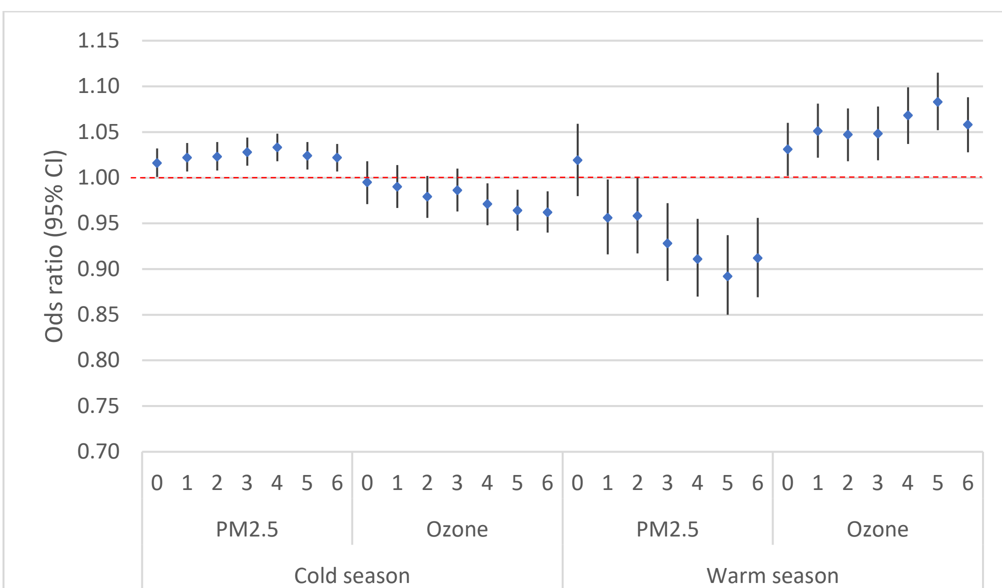
Figure 2.2. Associations between air pollution and asthma ED visits by season and lag



Models adjusted for temperature, humidity, and co-pollutants. Time-unvarying factors were controlled by study design. Estimates were obtained for each 5-unit increase in pollutants. The numbers on the x-axis represent lag, which can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc. Cold season: Nov. – Apr., warm season: May-Oct. Abbreviations: ED, emergency department; PM, particulate matter; CI, confidence intervals.

The effects of $PM_{2.5}$ and ozone on asthma hospitalization are similar to those of asthma ED visits described above (**Figure 2.3**, **Table 2.3**). A 5-unit increase in $PM_{2.5}$ exposure during the cold season is associated with about 2-3% increase in risk of being hospitalized for asthma within one week. During the warm season, a 5-unit increase in ozone is associated with a 5-8% increased risk of being hospitalized by asthma.

Figure 2.3. Associations between air pollution and asthma hospitalization by season and lag



Models adjusted for temperature, humidity, and co-pollutants. Time-unvarying factors were controlled by study design. Estimates were obtained for each 5-unit increase in pollutants. The numbers on the x-axis represent lag, which can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc. Cold season: Nov. – Apr., warm season: May-Oct. Abbreviations: ED, emergency department; PM, particulate matter; CI, confidence intervals.

Table 2.3. Estimates for associations between pollution and asthma ED visits and hospitalizations

Season	Pollutants	Lag[b]	OR (95% CI)[a]	
			Asthma ED visits	Asthma hospitalization
Cold (Nov.-Apr.)	$PM_{2.5}$	0	1.01 (1.00, 1.01)	**1.02 (1.00, 1.03)**
		1	1.01 (1.00, 1.02)	**1.02 (1.01, 1.04)**
		2	**1.02 (1.01, 1.02)**	**1.02 (1.01, 1.04)**
		3	**1.02 (1.02, 1.03)**	**1.03 (1.01, 1.04)**
		4	**1.02 (1.01, 1.03)**	**1.03 (1.02, 1.05)**
		5	**1.02 (1.01, 1.02)**	**1.02 (1.01, 1.04)**
		6	**1.02 (1.01, 1.02)**	**1.02 (1.01, 1.04)**
	Ozone	0	1.00 (0.99, 1.01)	1.00 (0.97, 1.02)
		1	0.99 (0.98, 1.00)	0.99 (0.97, 1.01)
		2	0.98 (0.97, 0.99)	0.98 (0.96, 1.00)
		3	0.97 (0.96, 0.98)	0.99 (0.96, 1.01)
		4	0.96 (0.95, 0.97)	0.97 (0.95, 0.99)
		5	0.96 (0.95, 0.97)	0.96 (0.94, 0.99)
		6	0.97 (0.96, 0.98)	0.96 (0.94, 0.99)
Warm (May-Oct.)	$PM_{2.5}$	0	**1.04 (1.02, 1.05)**	1.02 (0.98, 1.06)
		1	**1.03 (1.01, 1.04)**	0.96 (0.92, 1.00)
		2	1.01 (1.00, 1.02)	0.96 (0.92, 1.00)
		3	1.00 (0.99, 1.01)	0.93 (0.89, 0.97)
		4	0.98 (0.97, 1.00)	0.91 (0.87, 0.96)
		5	0.96 (0.95, 0.98)	0.89 (0.85, 0.94)
		6	0.95 (0.93, 0.96)	0.91 (0.87, 0.96)
	Ozone	0	1.00 (0.99, 1.01)	1.03 (1.00, 1.06)
		1	1.01 (1.00, 1.02)	**1.05 (1.02, 1.08)**
		2	**1.02 (1.01, 1.03)**	**1.05 (1.02, 1.08)**
		3	**1.03 (1.02, 1.04)**	**1.05 (1.02, 1.08)**
		4	**1.04 (1.03, 1.05)**	**1.07 (1.04, 1.10)**
		5	**1.04 (1.03, 1.05)**	**1.08 (1.05, 1.12)**
		6	**1.05 (1.04, 1.06)**	**1.06 (1.03, 1.09)**

[a]Models adjusted for temperature, humidity, and co-pollutants. Time-unvarying factors were controlled by study design. Estimates were obtained for each 5-unit increase in pollutants.
[b]Lag can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc.
Boldface font indicates statistical significance at $p<0.05$.
Abbreviations: ED, emergency department; $PM_{2.5}$, particulate matter <2.5 microns; OR, odds ratio; CI, confidence intervals.

Table 2.4 illustrates the associations between air pollution and asthma stratified by residents within and outside of the South Fresno AB 617 community's boundaries. Even at the same level of exposure, residents within the community boundaries may bear higher risks. For example, during the cold season, each 5-unit in $PM_{2.5}$ exposures increased the risk of asthma hospitalization by 5% for residents within the boundaries, but this exposure was not associated with risks among those outside the boundaries (**Table 2.4**).

Table 2.4. Associations between air pollution and asthma within and outside South Fresno AB 617 Community boundaries

Season	Pollutants	Lag[b]	OR (95% CI)[a]			
			ED visits		Hospitalizations	
			Within AB 617 boundaries	Outside AB 617 boundaries	Within AB 617 boundaries	Outside AB 617 boundaries
Cold	$PM_{2.5}$	0	**1.02 (1.01,1.04)**	1.01 (1.00,1.02)	**1.05 (1.02,1.08)**	0.99 (0.97,1.02)
		1	**1.03 (1.02,1.05)**	**1.01 (1.00,1.02)**	**1.05 (1.02,1.08)**	1.00 (0.98,1.02)
		2	**1.03 (1.02,1.05)**	**1.02 (1.01,1.03)**	**1.05 (1.03,1.08)**	1.01 (0.99,1.03)
		3	**1.03 (1.02,1.05)**	**1.02 (1.01,1.03)**	**1.05 (1.02,1.08)**	**1.02 (1.00,1.04)**
		4	**1.03 (1.01,1.04)**	**1.02 (1.01,1.03)**	**1.06 (1.03,1.09)**	**1.02 (1.00,1.04)**
		5	**1.02 (1.01,1.03)**	**1.01 (1.00,1.02)**	**1.04 (1.01,1.06)**	**1.02 (1.00,1.04)**
		6	**1.02 (1.00,1.03)**	**1.01 (1.00,1.02)**	**1.04 (1.01,1.07)**	**1.02 (1.00,1.04)**
	Ozone	0	1.00 (0.98,1.01)	1.01 (0.99,1.02)	1.01 (0.96,1.05)	0.97 (0.95,1.00)
		1	0.99 (0.98,1.01)	1.00 (0.99,1.01)	1.01 (0.97,1.06)	0.98 (0.96,1.01)
		2	0.99 (0.97,1.01)	1.00 (0.99,1.01)	0.97 (0.93,1.01)	0.99 (0.96,1.02)
		3	1.01 (0.99,1.02)	0.99 (0.98,1.00)	1.01 (0.97,1.05)	0.99 (0.96,1.02)
		4	0.99 (0.97,1.00)	0.99 (0.98,1.00)	1.01 (0.97,1.05)	0.98 (0.95,1.01)
		5	0.98 (0.96,1.00)	0.99 (0.98,1.00)	0.99 (0.95,1.03)	0.98 (0.96,1.01)
		6	0.99 (0.97,1.01)	1.00 (0.99,1.01)	0.98 (0.94,1.03)	0.98 (0.95,1.01)
Warm	$PM_{2.5}$	0	**1.03 (1.01,1.05)**	1.01 (1.00,1.02)	**1.06 (1.01,1.12)**	1.00 (0.96,1.04)
		1	**1.02 (1.01,1.04)**	1.01 (1.00,1.02)	1.01 (0.96,1.07)	1.00 (0.97,1.03)
		2	**1.02 (1.01,1.04)**	1.00 (0.99,1.01)	0.98 (0.92,1.03)	0.98 (0.95,1.02)
		3	1.02 (1.00,1.03)	1.01 (1.00,1.02)	0.94 (0.89,1.00)	0.98 (0.95,1.01)
		4	1.02 (0.98,1.02)	1.01 (1.00,1.02)	0.98 (0.93,1.04)	0.97 (0.94,1.00)
		5	1.00 (0.99,1.02)	1.00 (0.99,1.01)	0.97 (0.91,1.02)	0.96 (0.93,1.00)
		6	1.00 (0.99,1.02)	1.00 (0.99,1.01)	0.94 (0.89,1.00)	0.97 (0.94,1.01)
	Ozone	0	1.00 (0.97,1.02)	1.00 (0.99,1.01)	1.00 (0.95,1.06)	**1.05 (1.02,1.08)**
		1	1.01 (0.99,1.03)	1.00 (0.99,1.01)	1.02 (0.97,1.07)	**1.06 (1.02,1.09)**
		2	1.01 (0.99,1.03)	1.01 (1.00,1.02)	1.03 (0.98,1.08)	**1.05 (1.02,1.08)**
		3	1.01 (0.99,1.03)	1.01 (1.00,1.02)	1.03 (0.98,1.08)	**1.03 (1.00,1.07)**
		4	**1.02 (1.00,1.04)**	1.01 (1.00,1.02)	**1.06 (1.01,1.12)**	1.03 (1.00,1.06)
		5	1.00 (0.98,1.02)	1.01 (1.00,1.02)	**1.07 (1.02,1.12)**	1.04 (1.00,1.07)
		6	1.01 (0.99,1.03)	1.01 (1.00,1.02)	1.05 (1.00,1.10)	1.02 (0.99,1.05)

[a]Models adjusted for temperature, humidity, and co-pollutants. Time-unvarying factors were controlled by study design. Estimates were obtained for each 5-unit increase in pollutants.
[b]Lag can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc.
Boldface font indicates statistical significance at $p<0.05$
Abbreviations: ED, emergency department; $PM_{2.5}$, particulate matter <2.5 microns; OR, odds ratio; CI, confidence intervals.
Cold season: Nov. – Apr., warm season: May-Oct.

When stratified by race/ethnicity to explore whether specific groups may be more impacted by air pollution, we consistently observed that American Indian/Alaskan Native communities were more affected, even at the same level of exposure (**Table 2.5**). For example, each 5-unit increase in $PM_{2.5}$ exposures in the colder months increased the risk of ED visits by 40% among American Indian/Alaskan Natives, whereas these risks were about 2-3% in other groups.

A similar pattern was also observed for asthma hospitalization, but the estimates were imprecise due to the small sample size within this group (**Table 2.6**).

Table 2.5. Associations between air pollution and asthma ED visits by race/ethnicity

Season	Pollutants	Lag[b]	OR (95% CI)[a] Non-Hispanic White	Non-Hispanic Black	Hispanic	Asian/PI	American Indian/Alaskan Native	Other
Cold	**$PM_{2.5}$**	**0**	1.01 (1.00,1.03)	1.01 (0.99,1.03)	**1.01 (1.00,1.02)**	1.01 (0.97,1.05)	1.15 (0.85,1.55)	1.00 (0.94,1.05)
		1	**1.02 (1.00,1.03)**	1.02 (1.00,1.04)	**1.02 (1.01,1.03)**	1.00 (0.96,1.03)	1.21 (0.94,1.55)	1.00 (0.95,1.05)
		2	**1.02 (1.01,1.04)**	**1.03 (1.01,1.05)**	**1.02 (1.01,1.03)**	1.02 (0.98,1.05)	**1.40 (1.07,1.82)**	1.04 (0.99,1.09)
		3	**1.03 (1.01,1.04)**	**1.02 (1.00,1.04)**	**1.02 (1.01,1.03)**	1.02 (0.98,1.05)	**1.32 (1.00,1.74)**	**1.05 (1.00,1.10)**
		4	**1.02 (1.01,1.04)**	**1.02 (1.00,1.04)**	**1.02 (1.01,1.03)**	1.01 (0.97,1.04)	1.26 (0.98,1.62)	**1.06 (1.01,1.11)**
		5	**1.02 (1.00,1.03)**	1.00 (0.98,1.02)	**1.02 (1.01,1.03)**	1.00 (0.97,1.04)	1.23 (0.99,1.53)	1.02 (0.97,1.07)
		6	**1.02 (1.00,1.03)**	1.00 (0.98,1.03)	1.01 (1.00,1.02)	1.01 (0.97,1.05)	**1.30 (1.02,1.67)**	1.04 (0.99,1.09)
	Ozone	**0**	1.00 (0.98,1.02)	1.00 (0.97,1.03)	1.00 (0.99,1.02)	1.00 (0.95,1.05)	1.03 (0.74,1.43)	0.97 (0.90,1.04)
		1	0.99 (0.97,1.01)	1.02 (0.99,1.05)	1.00 (0.99,1.01)	1.02 (0.98,1.06)	0.93 (0.72,1.22)	0.99 (0.93,1.06)
		2	0.99 (0.97,1.01)	1.00 (0.98,1.03)	1.00 (0.98,1.01)	1.01 (0.97,1.06)	1.28 (0.91,1.81)	0.99 (0.93,1.05)
		3	0.98 (0.96,1.00)	1.00 (0.98,1.03)	1.00 (0.99,1.01)	1.00 (0.96,1.04)	1.32 (0.93,1.88)	0.97 (0.90,1.03)
		4	0.98 (0.96,1.00)	1.00 (0.97,1.02)	1.00 (0.98,1.01)	0.99 (0.94,1.03)	**1.66 (1.12,2.45)**	1.01 (0.95,1.07)
		5	0.99 (0.97,1.00)	0.98 (0.95,1.00)	0.99 (0.98,1.00)	1.00 (0.95,1.04)	1.08 (0.80,1.46)	1.04 (0.98,1.10)
		6	0.99 (0.98,1.01)	0.98 (0.96,1.01)	1.00 (0.99,1.01)	1.00 (0.96,1.05)	1.18 (0.83,1.67)	1.01 (0.95,1.08)
Warm	**$PM_{2.5}$**	**0**	1.02 (1.00,1.04)	1.01 (0.98,1.04)	**1.02 (.001,1.03)**	1.01 (0.96,1.06)	0.96 (0.77,1.20)	**1.07 (1.00,1.15)**
		1	1.01 (0.99,1.03)	1.02 (0.99,1.04)	1.01 (1.00,1.02)	1.01 (0.96,1.05)	0.92 (0.75,1.12)	**1.07 (1.01,1.14)**
		2	1.00 (0.99,1.02)	1.01 (0.98,1.03)	1.01 (0.99,1.02)	1.02 (0.98,1.06)	0.96 (0.78,1.18)	**1.10 (1.04,1.17)**
		3	1.01 (0.99,1.03)	1.01 (0.98,1.03)	1.01 (0.99,1.02)	1.03 (0.99,1.07)	1.10 (0.93,1.30)	**1.09 (1.03,1.16)**
		4	1.00 (0.98,1.02)	1.00 (0.97,1.03)	1.00 (0.99,1.01)	1.03 (0.99,1.07)	**1.17 (1.01,1.36)**	**1.09 (1.03,1.15)**
		5	1.00 (0.98,1.02)	0.99 (0.96,1.02)	1.00 (0.99,1.01)	1.02 (0.98,1.06)	1.11 (0.95,1.29)	1.06 (1.00,1.12)
		6	0.99 (0.98,1.01)	0.99 (0.96,1.01)	1.00 (0.99,1.01)	1.01 (0.97,1.05)	1.13 (0.96,1.34)	1.08 (1.02,1.14)
	Ozone	**0**	1.01 (0.98,1.03)	1.01 (0.98,1.04)	0.99 (0.98,1.01)	1.00 (0.94,1.05)	1.07 (0.86,1.33)	1.00 (0.92,1.08)
		1	**1.03 (1.00,1.05)**	0.99 (0.96,1.02)	1.00 (0.99,1.02)	0.96 (0.92,1.01)	1.09 (0.89,1.33)	1.00 (0.93,1.08)
		2	**1.02 (1.00,1.05)**	1.01 (0.98,1.04)	1.01 (0.99,1.02)	0.99 (0.94,1.04)	1.01 (0.85,1.20)	1.00 (0.92,1.08)
		3	1.00 (0.98,1.03)	1.00 (0.97,1.03)	**1.02 (1.00,1.03)**	0.98 (0.93,1.03)	1.05 (0.88,1.25)	1.00 (0.92,1.08)
		4	1.02 (1.00,1.04)	1.01 (0.98,1.04)	**1.02 (1.00,1.03)**	0.98 (0.93,1.03)	1.02 (0.84,1.23)	0.97 (0.90,1.04)
		5	1.00 (0.98,1.02)	1.00 (0.97,1.04)	1.01 (1.00,1.03)	0.97 (0.93,1.02)	1.09 (0.90,1.31)	0.95 (0.88,1.02)
		6	1.01 (0.99,1.04)	1.01 (0.98,1.04)	1.01 (1.00,1.03)	1.02 (0.97,1.07)	1.11 (0.93,1.34)	0.91 (0.85,0.99)

[a]Models adjusted for temperature, humidity, and co-pollutants. Time-unvarying factors were controlled by study design. Estimates were obtained for each 5-unit increase in pollutants.
[b]Lag can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc.
Boldface font indicates statistical significance at $p<0.05$.
Abbreviations: ED, emergency department; $PM_{2.5}$, particulate matter <2.5 microns; OR, odds ratio; CI, confidence intervals.
Cold season: Nov. – Apr., warm season: May-Oct.

Table 2.6. Associations between air pollution and asthma hospitalization by race/ethnicity

Season	Pollutants	Lag[b]	OR (95% CI)[a] Non-Hispanic White	Non-Hispanic Black	Hispanic	Asian/Pacific Islander	American Indian/Alaskan Native	Other
Cold	**$PM_{2.5}$**	**0**	1.01 (0.98,1.05)	1.01 (0.97,1.05)	1.01 (0.98,1.04)	1.01 (0.94,1.07)	1.22 (0.86,1.72)	1.08 (0.94,1.24)
		1	1.02 (0.99,1.05)	1.03 (0.99,1.07)	1.02 (0.99,1.05)	1.00 (0.94,1.07)	1.04 (0.82,1.33)	1.01 (0.89,1.15)
		2	1.02 (0.99,1.05)	1.03 (1.00,1.07)	1.02 (0.99,1.05)	1.05 (0.98,1.12)	1.11 (0.87,1.41)	1.04 (0.92,1.18)
		3	1.02 (0.99,1.05)	**1.06 (1.02,1.10)**	1.02 (1.00,1.05)	1.05 (0.98,1.12)	1.16 (0.85,1.58)	1.01 (0.89,1.14)
		4	1.01 (0.98,1.04)	**1.09 (1.05,1.13)**	1.03 (1.00,1.05)	1.05 (0.99,1.12)	0.99 (0.77,1.28)	0.96 (0.85,1.09)
		5	1.02 (0.99,1.05)	**1.05 (1.01,1.09)**	1.01 (0.99,1.04)	1.06 (1.00,1.12)	0.87 (0.65,1.15)	0.88 (0.77,1.01)
		6	1.02 (0.99,1.05)	1.02 (0.99,1.06)	1.02 (1.00,1.05)	**1.08 (1.02,1.15)**	0.93 (0.74,1.17)	0.90 (0.79,1.03)
	Ozone	**0**	0.97 (0.93,1.02)	0.99 (0.94,1.04)	0.98 (0.94,1.02)	0.92 (0.84,1.01)	1.41 (0.89,2.22)	1.23 (0.96,1.59)
		1	0.96 (0.92,1.00)	0.98 (0.93,1.03)	1.00 (0.96,1.04)	0.98 (0.90,1.08)	1.14 (0.80,1.61)	1.09 (0.89,1.33)
		2	0.97 (0.93,1.02)	0.98 (0.93,1.03)	0.98 (0.94,1.02)	0.96 (0.87,1.06)	0.98 (0.73,1.33)	1.00 (0.84,1.19)
		3	0.99 (0.95,1.04)	1.02 (0.97,1.08)	0.99 (0.96,1.03)	0.95 (0.87,1.05)	0.82 (0.59,1.15)	0.93 (0.77,1.12)

Season	Pollutants	Lag[b]	OR (95% CI)[a]					
			Non-Hispanic White	Non-Hispanic Black	Hispanic	Asian/Pacific Islander	American Indian/Alaskan Native	Other
		4	0.99 (0.95,1.04)	1.00 (0.94,1.05)	0.99 (0.96,1.03)	0.92 (0.84,1.00)	1.11 (0.81,1.51)	0.97 (0.81,1.18)
		5	1.00 (0.96,1.05)	0.96 (0.91,1.01)	1.01 (0.97,1.04)	0.92 (0.84,1.00)	1.35 (0.93,1.97)	0.97 (0.81,1.17)
		6	1.02 (0.98,1.07)	0.96 (0.91,1.01)	0.99 (0.95,1.03)	0.96 (0.88,1.05)	1.07 (0.74,1.55)	1.08 (0.90,1.28)
Warm	**$PM_{2.5}$**	**0**	1.03 (0.96,1.10)	0.97 (0.91,1.05)	1.01 (0.96,1.07)	0.99 (0.87,1.12)	0.35 (0.04,2.87)	0.91 (0.68,1.21)
		1	1.03 (0.97,1.09)	0.97 (0.91,1.03)	1.00 (0.96,1.05)	1.01 (0.90,1.14)	0.60 (0.14,2.69)	0.88 (0.66,1.18)
		2	1.02 (0.96,1.08)	0.92 (0.86,0.99)	0.99 (0.94,1.04)	0.98 (0.88,1.10)	2.34 (0.51,10.85)	0.91 (0.72,1.15)
		3	1.01 (0.95,1.07)	0.94 (0.88,1.00)	0.97 (0.92,1.02)	0.95 (0.84,1.08)	0.93 (0.31,2.83)	1.01 (0.86,1.19)
		4	1.02 (0.95,1.08)	0.95 (0.89,1.02)	0.98 (0.93,1.03)	0.90 (0.80,1.02)	1.62 (0.37,7.13)	0.99 (0.84,1.17)
		5	0.99 (0.93,1.05)	0.94 (0.88,1.01)	0.97 (0.92,1.02)	0.93 (0.83,1.04)	2.03 (0.55,7.40)	0.91 (0.73,1.14)
		6	1.00 (0.94,1.07)	0.93 (0.87,0.99)	0.96 (0.91,1.01)	0.99 (0.89,1.10)	1.09 (0.56,2.13)	0.89 (0.69,1.13)
	Ozone	**0**	**1.09 (1.03,1.15)**	1.04 (0.98,1.11)	1.01 (0.96,1.06)	1.03 (0.93,1.15)	1.03 (0.46,2.30)	1.27 (0.98,1.64)
		1	**1.06 (1.01,1.12)**	**1.08 (1.02,1.14)**	1.03 (0.99,1.08)	1.07 (0.97,1.17)	1.21 (0.52,2.81)	1.07 (0.87,1.31)
		2	1.02 (0.97,1.08)	**1.07 (1.01,1.14)**	**1.06 (1.01,1.11)**	1.00 (0.91,1.10)	0.71 (0.23,2.20)	1.10 (0.90,1.35)
		3	1.02 (0.97,1.07)	1.01 (0.96,1.08)	1.04 (1.00,1.09)	1.01 (0.92,1.11)	2.21 (0.80,6.09)	0.94 (0.77,1.14)
		4	1.04 (0.99,1.09)	1.05 (0.99,1.11)	1.04 (0.99,1.09)	1.06 (0.97,1.17)	1.21 (0.60,2.44)	0.96 (0.78,1.19)
		5	1.03 (0.98,1.09)	1.06 (0.99,1.12)	1.04 (0.99,1.08)	1.04 (0.94,1.14)	1.51 (0.65,3.51)	1.14 (0.92,1.41)
		6	1.00 (0.95,1.05)	1.06 (1.00,1.12)	1.01 (0.97,1.06)	1.02 (0.93,1.12)	0.89 (0.47,1.68)	1.17 (0.93,1.47)

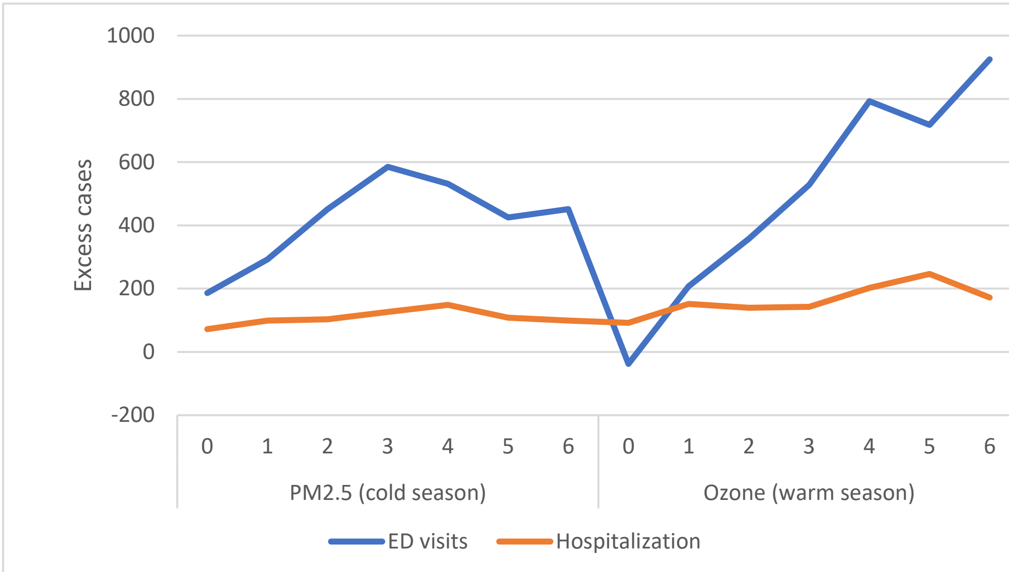
[a]Models adjusted for temperature, humidity, and co-pollutants. Time-unvarying factors were controlled by study design. Estimates were obtained for each 5-unit increase in pollutants.
[b]Lag can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc.
Boldface font indicates statistical significance at $p<0.05$.
Abbreviations: ED, emergency department; $PM_{2.5}$, particulate matter <2.5 microns; OR, odds ratio; CI, confidence intervals.
Cold season: Nov. – Apr., warm season: May-Oct.

2.3.3 EXCESS ASTHMA EVENTS DUE TO AIR POLLUTION EXPOSURES

Based on the risk estimates above, we also estimated the extent of asthma ED visits and hospitalizations that was attributed to $PM_{2.5}$ and ozone exposures in Fresno (**Figure 2.4**, **Table 2.7**). If people were exposed to 5 μg/m^3 less $PM_{2.5}$ during the cold season, that could have prevented 5.36-10.72 excess ED visits per 10,000 people, which is equivalent to a total of about293-585 ED visits during the study period. A similar reduction in cold season-$PM_{2.5}$ exposures could also have prevented 1.32-2.73 hospitalizations per 10,000 people, or a total of about 73-149 asthma hospitalizations.

Similarly, if warm-season ozone exposures were lowered by 5 parts per billion, that would have prevented approximately 1.69-4.52 asthma hospitalizations per 10,000 people, or a total of 92-247 cases. The same change in ozone levels would have also averted 6.57-17.0 asthma ED visits per 10,000 persons, equivalent to about 359-925 total cases.

Figure 2.4. Excess asthma associated with air pollution exposure in Fresno during the study period



Cold season: November – April; warm season: May – October. Lag can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc.
Abbreviations: ED, emergency department; $PM_{2.5}$, particulate matter <2.5 microns. Cold season: Nov. – Apr., warm season: May-Oct.

Table 2.7. Excess cases of asthma-related ED visits and hospitalizations associated with each 5-unit increase in air pollution exposures

Season	Pollutants	Lag[a]	Excess cases per 10,000 people (95% CI) Asthma ED visits	Asthma hospitalization	Total excess cases during study period Asthma ED visits	Asthma hospitalization
Cold	$PM_{2.5}$	0	3.41 (0.00, 6.33)	**1.32 (0.08, 2.64)**	186.03 (0.00, 345.49)	**72.13 (4.51, 144.26)**
		1	**5.36 (1.95, 8.28)**	**1.82 (0.58, 3.14)**	**292.34 (106.30, 451.79)**	**99.18 (31.56, 171.30)**
		2	**8.28 (4.87, 11.02)**	**1.90 (0.66, 3.22)**	**451.79 (265.76, 611.25)**	**103.68 (36.06, 175.81)**
		3	**10.72 (7.79, 14.13)**	**2.31 (1.07, 3.64)**	**584.67 (425.22, 770.70)**	**126.22 (58.60, 198.35)**
		4	**9.74 (6.82, 12.67)**	**2.73 (1.49, 3.97)**	**531.52 (372.06, 690.98)**	**148.76 (81.14, 216.38)**
		5	**7.79 (4.87, 11.20)**	**1.98 (0.74, 3.22)**	**425.22 (265.76, 611.25)**	**108.19 (40.57, 175.81)**
		6	**8.28 (5.36, 11.69)**	**1.82 (0.58, 3.06)**	**451.79 (292.34, 637.82)**	**99.18 (31.56, 166.80)**
	Ozone	0	0.00 (-4.87, 4.87)	-0.41 (-2.40, 1.49)	0.00 (-265.76, 265.76)	-22.54 (-130.73, 81.14)
		1	-6.33 (-11.20, -1.46)	-0.83 (-2.73, 1.16)	-345.49 (-611.25, -79.73)	-45.08 (-148.76, 63.11)
		2	-8.28 (-13.15, -3.90)	-1.74 (-3.64, 0.17)	-451.79 (-717.55, -212.61)	-94.67 (-198.35, 9.02)
		3	-14.13 (-19.00, -9.74)	-1.16 (-3.06, 0.83)	-770.70 (-1036.46, -531.52)	-63.11 (-166.80, 45.08)
		4	-18.02 (-22.89, -3.64)	-2.40 (-4.30, -0.50)	-983.31 (-1249.07, -744.13)	-130.73 (-234.42, -27.05)
		5	-19.49 (-23.87, -4.61)	-2.97 (-4.79, -1.07)	-1063.04 (-1302.22, -97.28)	-162.29 (-261.46, -58.60)
		6	-16.56 (-21.43, -2.18)	-3.14 (-4.96, -1.24)	-903.58 (-1169.34, -664.40)	-171.30 (-270.48, -67.62)
Warm	$PM_{2.5}$	0	**12.46 (8.31, 16.61)**	1.03 (-1.09, 3.21)	**679.64 (453.10, 906.19)**	56.45 (-59.42, 175.29)
		1	**8.65 (4.50, 12.46)**	-2.40 (-4.57, -0.11)	**471.97 (245.43, 679.64)**	-130.72 (-249.56, -5.94)
		2	4.15 (0.00, 8.31)	-2.29 (-4.52, 0.00)	226.55 (0.00, 453.10)	-124.78 (-246.59, 0.00)
		3	0.35 (-3.81, 4.84)	-3.92 (-6.15, -1.52)	18.88 (-207.67, 264.31)	-213.91 (-335.72, -83.19)
		4	-5.54 (-10.04, -1.04)	-4.85 (-7.08, -2.45)	-302.06 (-547.49, -56.64)	-264.42 (-386.23, -133.70)
		5	-12.80 (-17.65, -7.96)	-5.88 (-8.17, -3.43)	-698.52 (-962.83, -434.22)	-320.87 (-445.65, -187.17)
		6	-18.69 (-23.53, -3.50)	-4.79 (-7.13, -2.40)	-1019.47 (-1283.77, -36.28)	-261.45 (-389.20, -130.72)
	Ozone	0	-0.69 (-4.50, 3.11)	**1.69 (0.11, 3.27)**	-37.76 (-245.43, 169.91)	**92.10 (5.94, 178.26)**
		1	3.81 (0.00, 7.61)	**2.78 (1.20, 4.41)**	207.67 (0.00,415.34)	**151.52 (65.36, 240.65)**
		2	**6.57 (2.77, 10.38)**	**2.56 (0.98, 4.14)**	**358.70 (151.03, 566.37)**	**139.64 (53.48, 225.80)**

Season	Pollutants	Lag[a]	Excess cases per 10,000 people (95% CI) Asthma ED visits	Asthma hospitalization	Total excess cases during study period Asthma ED visits	Asthma hospitalization
		3	**9.69 (5.88, 13.5)**	**2.61 (1.03, 4.25)**	**528.61 (320.94, 736.28)**	**142.61 (56.45, 231.74)**
		4	**14.53 (10.73, 18.34)**	**3.70 (2.01, 5.39)**	**792.92 (585.25, 1000.59)**	**202.03 (109.93, 294.13)**
		5	**13.15 (9.34, 17.30)**	**4.52 (2.83, 6.26)**	**717.40 (509.73, 943.95)**	**246.59 (154.49, 341.67)**
		6	**16.96 (12.80, 20.76)**	**3.16 (1.52, 4.79)**	**925.07 (698.52, 1132.74)**	**172.32 (83.19, 261.45)**

[a]Lag can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc.
Boldface font indicates statistical significance at $p<0.05$.
Abbreviations: ED, emergency department; $PM_{2.5}$, particulate matter <2.5 microns; CI, confidence intervals.
Cold season: Nov. – Apr., warm season: May-Oct.

2.4 SUMMARY

We found that exposures to $PM_{2.5}$ and ozone may play a role in the risk of needing emergency care or hospitalization due to asthma. We also observed that while $PM_{2.5}$ had strong impacts all year, the impacts of ozone are more pronounced in the warm season when its concentration is usually high. Given people living close to pollution sources such as truck routes, freeways, and major roads may be exposed to higher concentrations of $PM_{2.5}$ and ozone, efforts to reduce exposures should be strengthened, especially within these areas. If $PM_{2.5}$ and ozone exposures were to be reduced on average by 5-unit, a significant number of asthma ED visits and hospitalizations could be prevented.

We also found that residents living in the South Fresno AB 617 community boundaries may experience higher risk even at the same level of exposure, and that racial/ethnic minorities are particularly more impacted by air pollution, suggesting that efforts to reduce health impacts in the AB 617 area are prudent. Given differences in impacts across areas and across demographics such as race/ethnicity, we expect that the impacts of basin air pollution in the Fresno area may not be uniform for all residents, making efforts to reduce air pollution exposures among those who are more impacted even more critical.

The analyses in this chapter have important strengths. First, HCAi captures all medical encounters; therefore, our cases are representative of cases in the city of Fresno. Second, the case-crossover nature of our analysis ensures minimal confounding by other factors that could also drive the risk of asthma.

2.5 RECOMMENDATIONS

Based on our findings, we offer the following recommendations:

1. Continue and strengthen previously mentioned efforts to reduce $PM_{2.5}$ and ozone (through a 1,000 foot-buffer), especially during their peak seasons.
2. Such efforts should consider communities that are potentially more impacted by air pollution, including those living within the AB 617 area, and particularly communities of color.
3. We also recommend the use of zero-emission commercial trucks when possible to minimize population exposure

CHAPTER 3. AIR POLLUTION AND CARDIO-CEREBROVASCULAR DISEASE IN FRESNO, CALIFORNIA

3.1 BACKGROUND

Cardio-cerebrovascular disease (CCVD) is an overarching category of serious health outcomes encompassing various heart and brain conditions associated with vascular issues, including atherosclerosis, hypertension (high blood pressure), myocardial hypertrophy, and strokes.[65] CCVDs can manifest independently, but can coexist in varying degrees.[66] CCVDs pose significant public health concerns, marked by high morbidity, high disability rate, frequent recurrences, and elevated mortality rates.[66] Roughly one out of three adults in California, equating to more than 8 million individuals, live with some form of CCVD.[67] CCVD is the number one cause of death and disability in California.[68] In Fresno County, heart disease was ranked the number one leading cause of death among residents in 2021.[69]

Studies around the world consistently linked air pollution exposures to CCVD. Recent systematic reviews and meta-analyses have suggested that exposures to both $PM_{2.5}$ and ozone are associated with CCVD risks.[70-75] Despite the high pollution and high burden of CCVD in Fresno, no studies have evaluated these impacts in this region.

The purpose of this chapter is to evaluate the impacts of $PM_{2.5}$ and ozone exposures on the risks of going to the emergency room or being hospitalized due to CCVD in the city of Fresno. We further estimated the number of excess cases due to air pollution, and explored whether certain subgroups of the population may be more impacted by air pollution.

3.2 METHODS

The approach for this study is similar to that described in Chapter 2.

3.2.1 DATA AND PARTCIPANTS

In this chapter, we examined data from the California Department of Health Care Access and Information (HCAi), including Emergency Department (ED) visits and Patient Discharge Data (PDD) between the years 2011 and 2020.[63] These are the latest available data. ED datasets consist of demographic, clinical, and facility information of all emergency department face-to-face encounters with a healthcare provider in California hospitals licensed to provide emergency medical services. Meanwhile, the PDD dataset consists of records for each inpatient discharge from any California-licensed hospital. Licensed hospitals can include general acute care, acute psychiatric care, chemical dependency recovery facilities, and psychiatric health facilities.

For this study, we only selected ED visits and hospitalizations from Fresno zip codes. We further restricted the datasets to ED visits and inpatient visits for those with the following cardio-cerebral vascular (CCVD) conditions as the primary diagnosis: acute myocardial infarction (stroke), heart failure, cardiac arrest, and cerebral infarction (stroke). We also note that, due to the lack of personally identifiable information, we cannot follow individuals longitudinally and we therefore have to treat each ED visit or hospitalization as an independent event. If someone visits the ED and ends up being admitted, the individual only shows up under the hospitalization data. In other words, no person would be counted twice for the same encounter.

3.2.2 EXPOSURE ASSESSMENT

We estimated daily exposures to $PM_{2.5}$ and ozone using an approach similar to that described in **Chapter 1, Section 1.2.2** and **Chapter 2 section 2.2.2.** Briefly, we obtained data for daily concentration of two common **air pollutants**, fine particulate matter less than 5 microns ($PM_{2.5}$, 24-hr. average $PM_{2.5}$) and ozone (maximum 8-hr. average), from the Air District. These daily concentrations were estimated by the Air District using a regression-based mathematical model with inputs from local air monitors and the Community Multilevel Air Quality (CMAQ) model output from the California Air Resources Board.[47,48] The data was estimated at the zip code level for spatiotemporal linkages to the health data. Participants were then spatiotemporally linked to daily air pollution data based on their residential zip code at the time of the event. We specifically focused on acute air pollution exposure and its effects within 7 days.

Due to the lack of residential addresses from HCAi datasets, we were unable to geocode participants for detailed spatial analyses more granular than the zip code (like those in Chapter 1).

3.2.3 OUTCOME ASSESSMENT

We utilized the 9th and 10th version of the International Classification of Disease codes with clinical modification (ICD-9-CM and ICD-10-CM) to identify cardio-cerebral vascular conditions (CCVD) ED visits and hospitalizations. The codes used to identify specific CCVD conditions are presented in **Table 3.1**.

Table 3.1. ICD codes to identify cardio-cerebral vascular diseases

CCVD conditions	ICD 9 CM	ICD 10 CM
Acute myocardial infarction (heart attack)	"410"	"I21", "I22"
Heart failure	"428"	"I50"
Cardiac arrest	"427"	"I46"
Cerebral infarction (stroke)	"430", "431", "432", "433", "434", "435"	"I60", "I61", "I62", "I63"

Abbreviations: ICD, International Classification of Disease codes; CM, clinical modification; CCVD, cardio cerebral vascular disease.

3.2.4 STATISTICAL ANALYSIS

To determine the impacts of air pollution on CCVD in Fresno, we employed the time-stratified case-crossover analysis to minimize confounding by factors that can also explain risks of asthma. A detailed description of this method is described in **Chapter 1** and **Chapter 2** above. Briefly, in this analysis, we only selected cases that were impacted by CCVD (any, or specific CCVD). We then compared exposures (i.e., $PM_{2.5}$ and ozone) during a hazard period shortly before the event to exposures during control periods during which the event did not happen. The hazard period was defined as the day of event (lag 0) and each of the six days before the event (lags 1-6). Control periods were selected using the time-stratified approach, where controls were selected as the same day of the week within the same month as the case period.[52] For example, if someone visited the ED or got hospitalized because of CCVD on Monday, March 12, 2018, then this will be the case period (lag 0). The control period will be selected as Mondays the 5th, the 19th, and the 26th of the same month of March **(Figure 1.2)**. This approach allows control for days of the week and month and minimizes time-trend bias. Since the comparisons were made for the same person, this approach allows complete control for non-time-varying confounders (or factors that could explain the observed associations). Conditional logistic regression models were used to estimate the risks of CCVD associated with a 5-unitincrease in air pollution exposures. We found meaningful seasonal differences and presented results by season. We additionally explored effects by AB 617 residence status and race/ethnicity.

We then calculated the access number of CCVD ED visits and hospitalizations due to pollution, also known as the attributable risk (AR), using the following formula:

$$AR = I_e - I_u$$

where I_u is the background rate of event in the population, and I_e is the incidence of events among those exposed to higher pollutants and is calculated as I_u times the odds ratio. I_u was calculated as the number of events in Fresno divided by the total population estimated by the 2020 census (n=545,567).[64]

All analyses were completed in ArcGIS Pro (Redlands, CA), SAS 9.2 (Cary, NC) and Microsoft Excel (Redmond, WA).

3.3 RESULTS

3.3.1 DESCRIPTIVE STATISTICS

Table 3.2 describes the characteristics of our study participants. The analyses include 12,843 CCVD ED visits and 40,607 hospitalizations. The majority of CCVD ED visits (~50%) are due to cardiac arrest. ED patients were mostly older, male, non-Hispanic Whites, spoke English, or had private insurance as the principal source of payment. Most patients who ended up being hospitalized were admitted for stroke (37%). Most of them were also older, male, non-Hispanic White, spoke English, or had Medicare as principal source of payment.

Table 3.2. Characteristics of emergency department visits and hospitalizations related to cardiovascular diseases in Fresno, 2011-2020

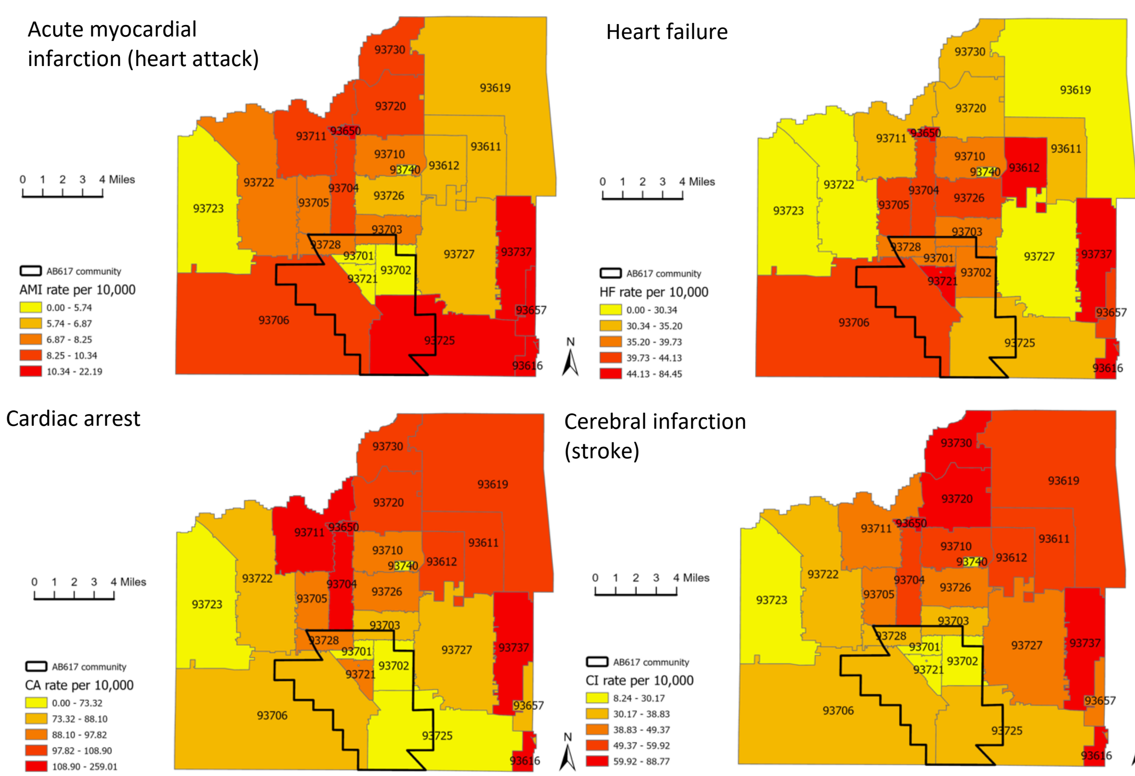
Characteristics	ED visits n= 12842(%)	Hospitalization n= 40607 (%)
CCVD conditions		
Acute myocardial infarction (heart attack)	606 (4.7)	10129 (24.9)
Heart failure	2600 (20.3)	10372 (25.5)
Cardiac arrest	6427 (50.1)	5173 (12.7)
Cerebral infarction (stroke)	3209 (25.0)	14933 (36.7)
Age categories		
0-4	124 (1.0)	67 (0.1)
5-17	151 (1.2)	104 (0.2)
18-64	5734 (44.7)	16231 (39.9)
65+	6833 (53.2)	24205 (59.6)
Sex		
Female	6140 (47.8)	19005 (46.8)
Male	6701 (52.2)	21602 (53.2)
Unknown	1 (0.0)	0 (0.0)
Race/ethnicity		
Non-Hispanic White	6242 (48.6)	18514 (45.5)
Non-Hispanic Black	683 (5.3)	3125 (7.7)
Hispanic	4979 (38.8)	9564 (23.5)
Asian/Pacific Islander	512 (3.9)	3036 (7.4)
American Indian/Alaskan Natives	41 (0.3)	121 (0.3)
Other	217 (1.6)	723 (1.7)
Unknown	168 (1.3)	5524 (13.6)
Principal language		
English	11697 (91.1)	34767 (85.6)
Spanish	752 (5.9)	3495 (8.6)
Other	393 (3.01)	2345 (5.7)
Expected source of payment		
Medicare	4070 (31.7)	24457 (60.2)
Medi-Cal	2404 (18.7)	8328 (20.5)
Private	5167 (40.2)	5635 (13.8)
Self-pay	774 (6.0)	892 (2.2)
Other	427 (3.3)	1294 (3.1)
Unknown	-	1 (0.0)
Season of service		

Characteristics	ED visits n= 12842(%)	Hospitalization n= 40607 (%)
Warm (May – October)	6455 (49.7)	19638 (48.3)
Cold (November – April)	6387 (50.3)	20969 (51.6)
Year of service		
2011	1585 (12.3)	5529 (13.6)
2012	1620 (12.6)	5516 (13.6)
2013	1789 (13.9)	5522 (13.6)
2014	1812 (14.1)	5327 (13.1)
2015	1564 (12.2)	4007 (9.9)
2016	1003 (7.8)	3875 (9.5)
2017	893 (7.0)	2823 (7.0)
2018	957 (7.5)	2804 (6.9)
2019	794 (6.2)	2741 (6.8)
2020	825 (6.4)	2404 (5.9)

Abbreviations: ED, emergency department; CCVD, cardio cerebral vascular disease.

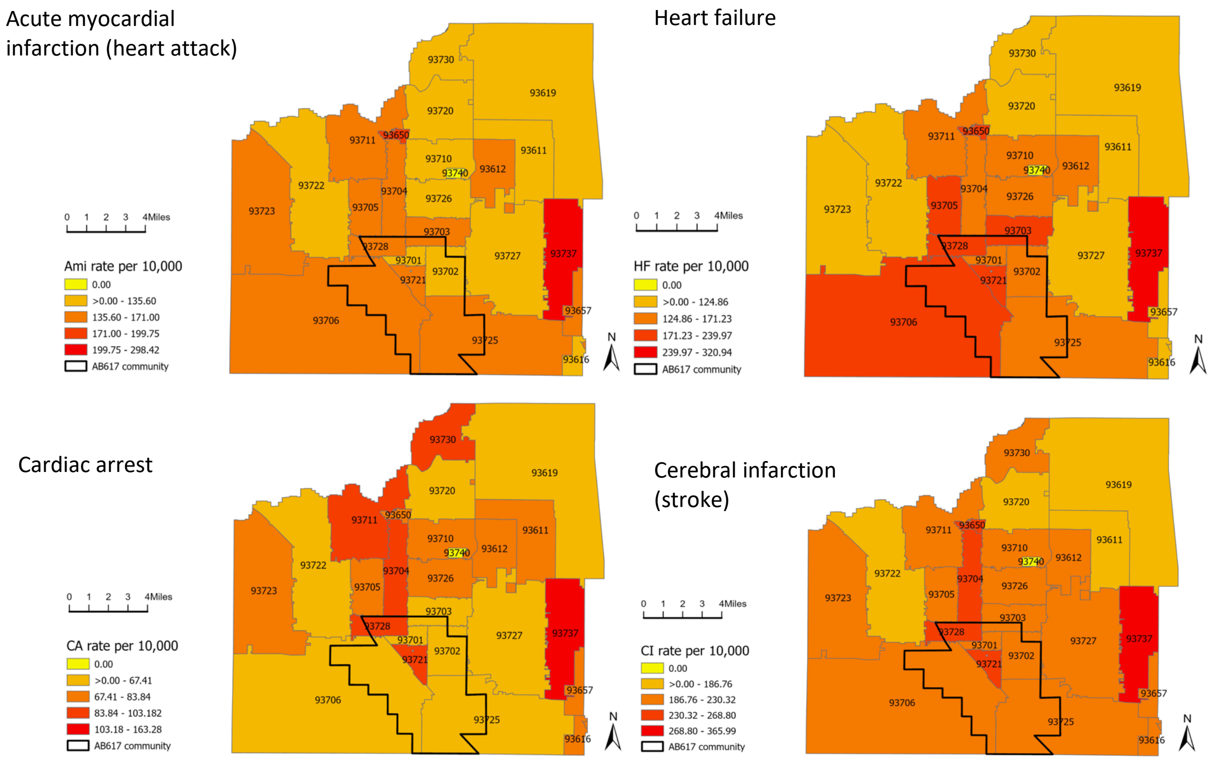
ED visits and hospitalization rates for CCVD ED visits varied by zip code. While rates of cardiac arrest and stroke appeared more pronounced in the northeastern part of the city, rates of heart attack and heart failure were more varied. CCVD hospitalizations appeared generally higher in the central and southwestern region of the city, but rates were also sporadically higher in certain zip codes for reasons we do not have data to investigate.

Figure 3.1. Distribution of CCVD ED visits by zip codes



Rates were estimated by taking the total cases during the study period divided by the total population in each zip code from the 2020 census.
Abbreviations: ED, emergency department; CCVD, cardio cerebral vascular disease.

Figure 3.2. Distribution of CCVD hospitalizations by zip codes



Rates were estimated by taking the total cases during the study period divided by the total population in each zip code from the 2020 census.
Abbreviations: CCVD, cardio cerebral vascular disease.

When rates were calculated separately for zip codes within and outside the AB 617 community boundaries, a few conditions were, on average, slightly higher within the boundaries (**Table 3.3**).

Table 3.3. Rates of CCVD within and outside of the Fresno AB 617 community boundaries

		Rates per 10,000 population	
		Within boundaries	Outside boundaries
ED visits	Acute myocardial infarction (heart attack)	7.60	9.74
	Heart failure	39.86	37.46
	Cardiac arrest	78.70	102.47
	Cerebral infarction (stroke)	30.32	52.88
Hospitalizations	Acute myocardial infarction (heart attack)	146.88	141.81
	Heart failure	183.95	135.26
	Cardiac arrest	68.97	77.54
	Cerebral infarction (stroke)	227.65	205.33

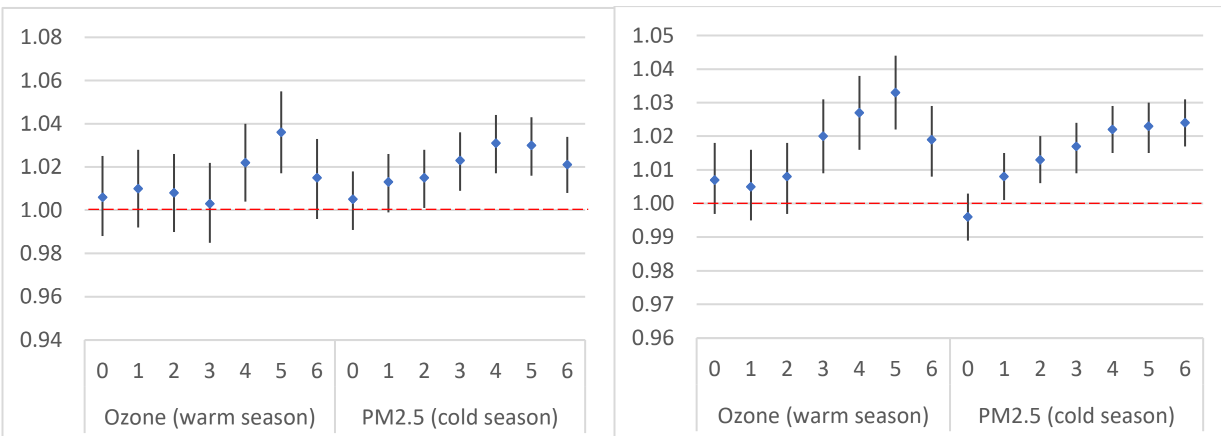
Abbreviations: ED, emergency department.

3.3.2 EFFECTS OF AIR POLLUTION ON CARDIO-CEREBRAL VASCULAR EVENTS

Exposures to $PM_{2.5}$ and ozone were both positively associated with CCVD events, but these associations varied by season, where the detrimental effects of $PM_{2.5}$ and ozone were only observed in the cold and warm season, respectively (**Figure 3.2, Table 3.4**). Each 5-unit increase in ozone was associated with a 2-4% increased risk of CCVD events within 4-6 days. $PM_{2.5}$ was linked to increased incidents of CCVD as soon as one day after exposure and the risks increased over the next few days.

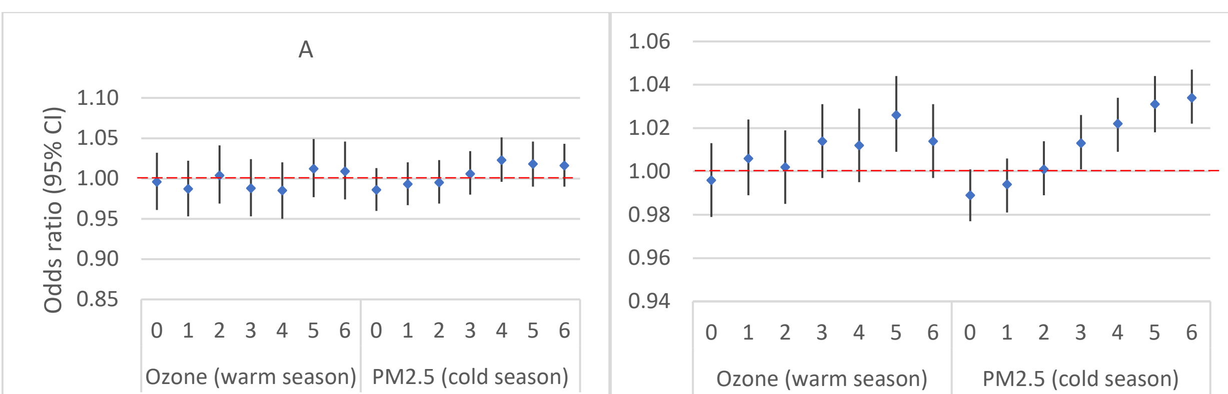
The associations remained consistent when we separated the analyses for specific CCVD types, including stroke (**Figure 3.3**), heart attack (**Figure 3.4**), cardiac arrest (**Figure 3.5**), and heart failure (**Figure 3.6**).

Figure 3.3. Associations between air pollution and ED visits (A) and hospitalizations (B) for all cardio-cerebral vascular events



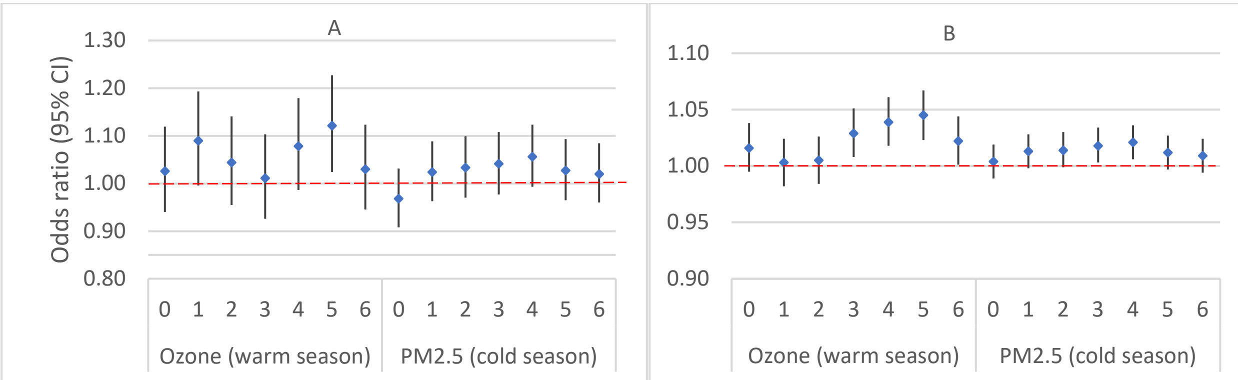
Models adjusted for temperature, humidity, and co-pollutants. Time-unvarying factors were controlled by study design. Estimates were obtained for each 5-unit increase in pollutants. Cold season: Nov. – Apr., warm season: May-Oct. Numbers on x-axis represent lags, which can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc. Abbreviations: ED, emergency department; $PM_{2.5}$, particulate matter <2.5 microns.

Figure 3.4. Associations between air pollution and ED visits (A) and hospitalizations (B) for stroke



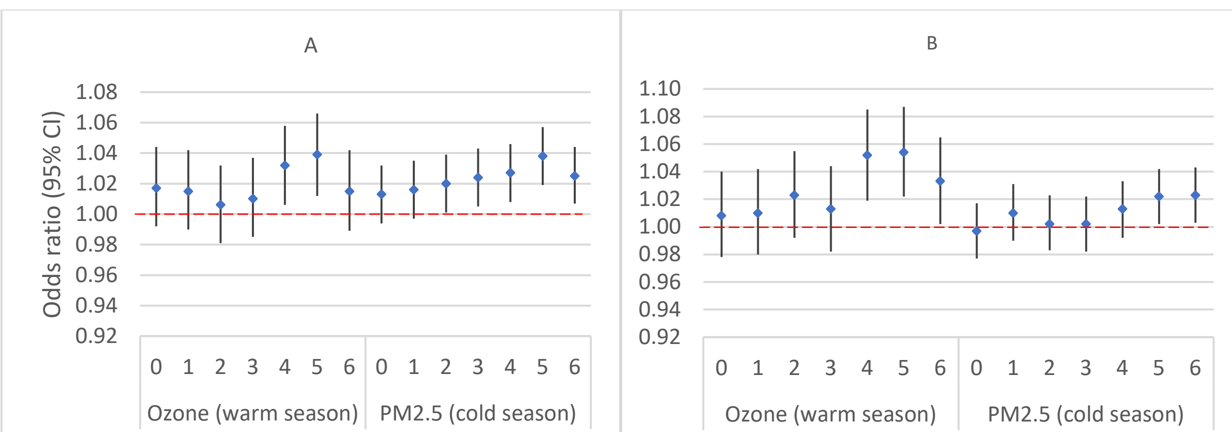
Models adjusted for temperature, humidity, and co-pollutants. Time-unvarying factors were controlled by study design. Estimates were obtained for each 5-unit increase in pollutants. Cold season: Nov. – Apr., warm season: May-Oct. Numbers on x-axis represent lags, which can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc. Abbreviations: ED, emergency department; $PM_{2.5}$, particulate matter <2.5 microns.

Figure 3.5. Associations between air pollution and ED visits (A) and hospitalizations (B) for acute myocardial infarction (heart attack)



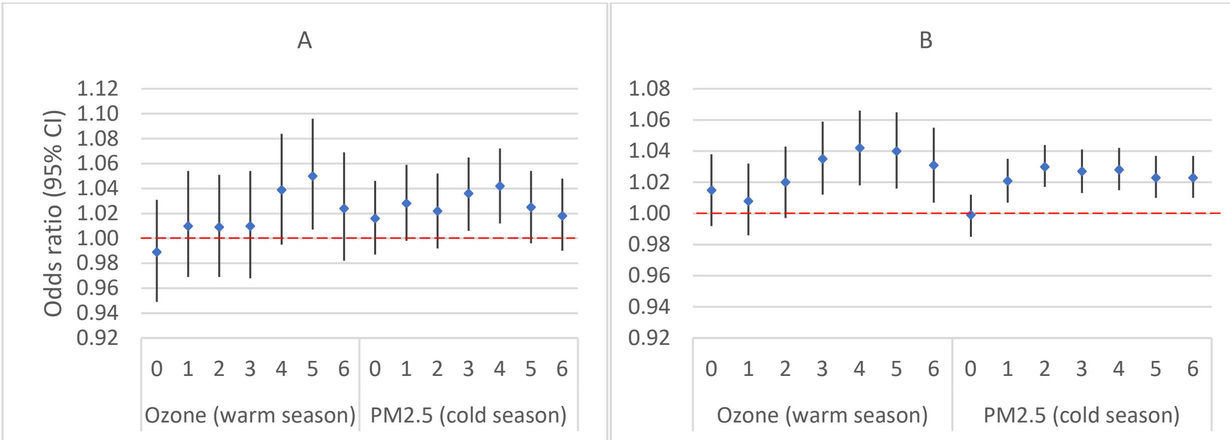
Models adjusted for temperature, humidity, and co-pollutants. Time-unvarying factors were controlled by study design. Estimates were obtained for each 5-unit increase in pollutants. Cold season: Nov. – Apr., warm season: May-Oct. Numbers on x-axis represent lags, which can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc. Abbreviations: ED, emergency department; $PM_{2.5}$, particulate matter <2.5 microns.

Figure 3.6. Associations between air pollution and ED visits (A) and hospitalizations (B) for cardiac arrest



Models adjusted for temperature, humidity, and co-pollutants. Time-unvarying factors were controlled by study design. Estimates were obtained for each 5-unit increase in pollutants. Cold season: Nov. – Apr., warm season: May-Oct. Numbers on x-axis represent lags, which can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc. Abbreviations: ED, emergency department; $PM_{2.5}$, particulate matter <2.5 microns.

Figure 3.7. Associations between air pollution and ED visit (A) and hospitalization (B) for heart failure



Models adjusted for temperature, humidity, and co-pollutants. Time-unvarying factors were controlled by study design. Estimates were obtained for each 5-unit increase in pollutants. Cold season: Nov. – Apr., warm season: May-Oct. Numbers on x-axis represent lags, which can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc. Abbreviations: ED, emergency department; $PM_{2.5}$, particulate matter <2.5 microns.

Table 3.4. Associations between pollution and cardio-cerebral vascular ED visits and hospitalizations

		OR (95% CI)				
	Lag	Any CCVD	Stroke	Heart attack	Cardiac arrest	Heart failure
ED visits						
Ozone (warm season, May-Oct.)	0	1.01 (0.99,1.03)	1.00 (0.96,1.03)	1.03 (0.94,1.12)	1.02 (0.99,1.04)	0.99 (0.95,1.03)
	1	1.01 (0.99,1.03)	0.99 (0.95,1.02)	**1.09 (1.00,1.19)**	1.02 (0.99,1.04)	1.01 (0.97,1.05)
	2	1.01 (0.99,1.03)	1.00 (0.97,1.04)	1.04 (0.96,1.14)	1.01 (0.98,1.03)	1.01 (0.97,1.05)
	3	1.00 (0.99,1.02)	0.99 (0.95,1.02)	1.01 (0.93,1.10)	1.01 (0.99,1.04)	1.01 (0.97,1.05)
	4	**1.02 (1.00,1.04)**	0.99 (0.95,1.02)	1.08 (0.99,1.18)	**1.03 (1.01,1.06)**	1.04 (1.00,1.08)
	5	**1.04 (1.02,1.06)**	1.01 (0.98,1.05)	**1.12 (1.02,1.23)**	**1.04 (1.01,1.07)**	**1.05 (1.01,1.10)**
	6	**1.02 (1.00,1.03)**	1.01 (0.97,1.05)	1.03 (0.95,1.12)	1.02 (0.99,1.04)	1.02 (0.98,1.07)
$PM_{2.5}$ (cold season, Nov.-Apr.)	0	1.01 (0.99,1.02)	0.99 (0.96,1.01)	0.97 (0.91,1.03)	1.01 (0.99,1.03)	1.02 (0.99,1.05)
	1	1.01 (1.00,1.03)	0.99 (0.97,1.02)	1.02 (0.96,1.09)	1.02 (1.00,1.04)	1.03 (1.00,1.06)
	2	1.02 (1.00,1.03)	1.00 (0.97,1.02)	1.03 (0.97,1.10)	1.02 (1.00,1.04)	1.02 (0.99,1.05)
	3	**1.02 (1.01,1.04)**	1.01 (0.98,1.03)	1.04 (0.98,1.11)	**1.02 (1.01,1.04)**	**1.04 (1.01,1.07)**
	4	**1.03 (1.02,1.04)**	**1.02 (1.00,1.05)**	1.06 (0.99,1.12)	**1.03 (1.01,1.05)**	**1.04 (1.01,1.07)**
	5	**1.03 (1.02,1.04)**	1.02 (0.99,1.05)	1.03 (0.97,1.09)	**1.04 (1.02,1.06)**	1.03 (1.00,1.05)
	6	**1.02 (1.01,1.03)**	1.02 (0.99,1.04)	1.02 (0.96,1.08)	**1.03 (1.01,1.04)**	1.02 (0.99,1.05)
Hospitalization						
Ozone (warm season, May – Oct.)	0	1.01 (1.00,1.02)	1.00 (0.98,1.01)	1.02 (.001,1.04)	1.01 (0.98,1.04)	1.02 (0.99,1.04)
	1	1.01 (1.00,1.02)	1.01 (0.99,1.02)	1.00 (0.98,1.02)	1.01 (0.98,1.04)	1.01 (0.99,1.03)
	2	1.01 (1.00,1.02)	1.00 (0.99,1.02)	1.01 (0.98,1.03)	1.02 (0.99,1.06)	1.02 (1.00,1.04)
	3	**1.02 (1.01,1.03)**	1.01 (1.00,1.03)	**1.03 (1.01,1.05)**	1.01 (0.98,1.04)	**1.04 (1.01,1.06)**
	4	**1.03 (1.02,1.04)**	1.01 (1.00,1.03)	**1.04 (1.02,1.06)**	**1.05 (1.02,1.09)**	**1.04 (1.02,1.07)**
	5	**1.03 (1.02,1.04)**	**1.03 (1.01,1.04)**	**1.05 (1.02,1.07)**	**1.05 (1.02,1.09)**	**1.04 (1.02,1.07)**
	6	**1.02 (1.01,1.03)**	1.01 (1.00,1.03)	**1.02 (1.00,1.04)**	**1.03 (1.00,1.07)**	**1.03 (1.01,1.06)**
$PM_{2.5}$ (cold season, Nov.-Apr.)	0	1.00 (0.99,1.00)	0.99 (0.98,1.00)	1.00 (0.99,1.02)	1.00 (0.98,1.02)	1.00 (0.99,1.01)
	1	1.01 (1.00,1.02)	0.99 (0.98,1.01)	1.01 (1.00,1.03)	1.01 (0.99,1.03)	**1.02 (1.01,1.04)**
	2	**1.01 (1.01,1.02)**	1.00 (0.99,1.01)	1.01 (1.00,1.03)	1.00 (0.98,1.02)	**1.03 (1.02,1.04)**
	3	**1.02 (1.01,1.02)**	1.01 (1.00,1.03)	1.02 (1.00,1.03)	1.00 (0.98,1.02)	**1.03 (1.01,1.04)**
	4	**1.02 (1.02,1.03)**	**1.02 (1.01,1.03)**	**1.02 (1.01,1.04)**	1.01 (0.99,1.03)	**1.03 (1.02,1.04)**
	5	**1.02 (1.02,1.03)**	**1.03 (1.02,1.04)**	1.01 (1.00,1.03)	**1.02 (1.00,1.04)**	**1.02 (1.01,1.04)**
	6	**1.02 (1.02,1.03)**	**1.03 (1.02,1.05)**	1.01 (0.99,1.02)	**1.02 (1.00,1.04)**	**1.02 (1.01,1.04)**

Models adjusted for temperature, humidity, and co-pollutants. Time-unvarying factors were controlled by study design. Estimates were obtained for each 5-unit increase in pollutants. Cold season: Nov. – Apr., warm season: May-Oct. Numbers on x-axis represent lags, which can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc. Abbreviations: ED, emergency department; $PM_{2.5}$, particulate matter <2.5 microns; CCVD, cardio cerebral vascular disease; OR, odds ration; CI, confidence intervals.
Boldface font indicates statistical significance at p<0.05

When analyzed separately for Fresno residents within and outside of the South Fresno AB 617 community boundaries, we observed that the effects of air pollution on CCVD were more consistent, stronger, and more immediate among those who lived within the boundaries (**Table 3.5**).

Table 3.5. Associations between air pollution and cardio-cerebral vascular diseases within and outside the South Fresno community boundaries

Season	Pollutants	Lag[b]	OR (95% CI)[a]			
			ED visits		Hospitalization	
			Within AB 617 boundaries	Outside AB 617 boundaries	Within AB 617 boundaries	Outside AB 617 boundaries
	$PM_{2.5}$	0	**1.03 (1.00,1.07)**	0.99 (0.98,1.01)	**1.02 (1.00,1.03)**	1.00 (0.99,1.01)
Cold (Nov.-Apr.)		1	**1.04 (1.01,1.07)**	1.00 (0.99,1.02)	**1.02 (1.01,1.04)**	1.01 (1.00,1.02)
		2	**1.04 (1.01,1.07)**	1.01 (0.99,1.02)	**1.02 (1.00,1.03)**	1.01 (1.00,1.02)
		3	**1.04 (1.00,1.07)**	**1.02 (1.00,1.03)**	**1.03 (1.01,1.04)**	**1.01 (1.00,1.02)**
		4	**1.03 (1.00,1.06)**	**1.02 (1.01,1.04)**	1.00 (0.98,1.03)	**1.02 (1.01,1.03)**
		5	0.97 (0.93,1.02)	**1.02 (1.01,1.04)**	1.00 (0.98,1.02)	**1.02 (1.01,1.03)**
		6	1.01 (0.97,1.06)	**1.02 (1.00,1.03)**	1.01 (0.99,1.03)	**1.02 (1.01,1.03)**
Warm (May-Oct.)	Ozone	0	1.04 (1.00,1.08)	1.01 (0.99,1.03)	1.01 (0.99,1.03)	1.01 (1.00,1.02)
		1	1.03 (0.99,1.07)	1.00 (0.98,1.02)	1.00 (0.98,1.02)	1.00 (0.99,1.02)
		2	1.03 (0.99,1.07)	1.00 (0.98,1.01)	**1.02 (1.00,1.05)**	0.99 (0.98,1.00)
		3	1.02 (0.98,1.06)	1.00 (0.98,1.02)	1.00 (0.98,1.03)	1.00 (0.99,1.02)
		4	1.02 (0.98,1.06)	1.00 (0.99,1.02)	**1.02 (1.00,1.03)**	1.02 (1.00,1.03)
		5	**1.03 (1.00,1.07)**	1.01 (0.99,1.03)	**1.02 (1.01,1.04)**	1.01 (1.00,1.02)
		6	**1.04 (1.01,1.07)**	1.00 (0.98,1.02)	**1.02 (1.00,1.03)**	1.01 (1.00,1.02)

[a]Models adjusted for temperature, humidity, and co-pollutants. Time-unvarying factors were controlled by study design. Estimates were obtained for each 5-unit increase in pollutant. [b]Lags can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc.
Abbreviations: ED, emergency department; $PM_{2.5}$, particulate matter <2.5 microns; OR, odds ration; CI, confidence intervals. Boldface font indicates statistical significance at p<0.05

In further stratified analyses, we observed that while air pollution increased the risk of having a CCVD event, these effects varied by race/ethnicity. We observed that the associations were more apparent among non-Hispanic Black and Hispanic persons (**Table 3.6**, **Table 3.7**). For example, while we observed no association between air pollution and CCVD events among White residents, ozone effects on ED visits were pronounced among Black resident in the warm season, and $PM_{2.5}$ effects were significant among Hispanics in the cold season (**Table 3.6**). We also observed the highest risk estimates among American Indian/Alaskan Native residents, although these effect estimates had wider confidence intervals due to small sample size.

Table 3.6. Associations between air pollution and cardio-cerebral vascular ED visits by race/ethnicity

		OR (95% CI)[a]					
Pollutants	**Lag[b]**	**Non-Hispanic White**	**Non-Hispanic Black**	**Hispanic**	**Asian/Pacific Islander**	**American Indian/Alaskan Native**	**Other**
Cold season $PM_{2.5}$	**0**	0.99 (0.97,1.01)	1.00 (0.93,1.07)	1.00 (0.98,1.03)	1.03 (0.95,1.11)	0.78 (0.34,1.80)	0.94 (0.83,1.07)
	1	1.00 (0.98,1.02)	1.00 (0.94,1.06)	1.01 (0.99,1.03)	1.04 (0.98,1.11)	1.18 (0.82,1.68)	0.94 (0.83,1.06)
	2	1.01 (0.99,1.03)	1.02 (0.95,1.08)	1.01 (0.99,1.04)	1.01 (0.95,1.08)	1.28 (0.82,1.98)	1.02 (0.90,1.15)
	3	1.01 (0.99,1.03)	1.00 (0.95,1.06)	**1.03 (1.01,1.05)**	1.03 (0.96,1.10)	1.43 (0.88,2.32)	1.07 (0.96,1.20)
	4	1.02 (1.00,1.04)	1.01 (0.95,1.07)	**1.03 (1.00,1.05)**	1.05 (0.98,1.12)	1.19 (0.86,1.66)	1.07 (0.96,1.20)
	5	1.02 (1.00,1.04)	0.99 (0.93,1.05)	**1.03 (1.01,1.06)**	1.04 (0.97,1.11)	1.44 (0.85,2.46)	1.07 (0.95,1.19)
	6	1.01 (0.99,1.03)	0.99 (0.93,1.05)	**1.04 (1.02,1.06)**	1.00 (0.94,1.07)	0.89 (0.57,1.38)	1.06 (0.95,1.18)
Warm season ozone	**0**	1.00 (0.97,1.02)	1.05 (0.97,1.13)	0.99 (0.96,1.02)	1.05 (0.96,1.15)	0.91 (0.68,1.22)	1.07 (0.89,1.28)
	1	1.01 (0.98,1.03)	1.06 (0.99,1.14)	1.00 (0.97,1.02)	1.03 (0.95,1.12)	0.85 (0.62,1.16)	1.04 (0.89,1.23)
	2	1.02 (0.99,1.05)	1.00 (0.93,1.08)	0.98 (0.96,1.01)	1.02 (0.95,1.10)	0.97 (0.70,1.34)	1.05 (0.88,1.26)
	3	1.00 (0.97,1.02)	1.01 (0.94,1.08)	1.00 (0.97,1.03)	1.03 (0.95,1.11)	0.86 (0.61,1.22)	1.17 (0.98,1.40)
	4	1.00 (0.97,1.02)	1.06 (0.98,1.14)	1.01 (0.98,1.04)	1.04 (0.97,1.13)	0.80 (0.59,1.07)	1.05 (0.90,1.24)
	5	1.00 (0.98,1.03)	**1.08 (1.01,1.16)**	1.01 (0.98,1.04)	0.96 (0.89,1.03)	1.19 (0.86,1.64)	1.03 (0.88,1.20)
	6	1.00 (0.98,1.03)	**1.10 (1.03,1.18)**	1.00 (0.97,1.03)	0.96 (0.89,1.03)	1.19 (0.85,1.67)	0.89 (0.75,1.06)

[a]Models adjusted for temperature, humidity, and co-pollutants. Time-unvarying factors were controlled by study design. Estimates were obtained for each 5-unit increase in pollutants. Cold season: Nov. – Apr., warm season: May-Oct.
[b]Lag can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc. Abbreviations: $PM_{2.5}$, particulate matter <2.5 microns; OR, odds ration; CI, confidence intervals. Boldface indicate statistical significance at p<0.05.

Findings on the association between air pollution and CCVD hospitalizations are presented in **Table 3.7**. We observed stronger and more consistent associations among Asian/Pacific Islanders.

Table 3.7. Associations between air pollution and cardio-cerebral vascular disease hospitalizations by race/ethnicity

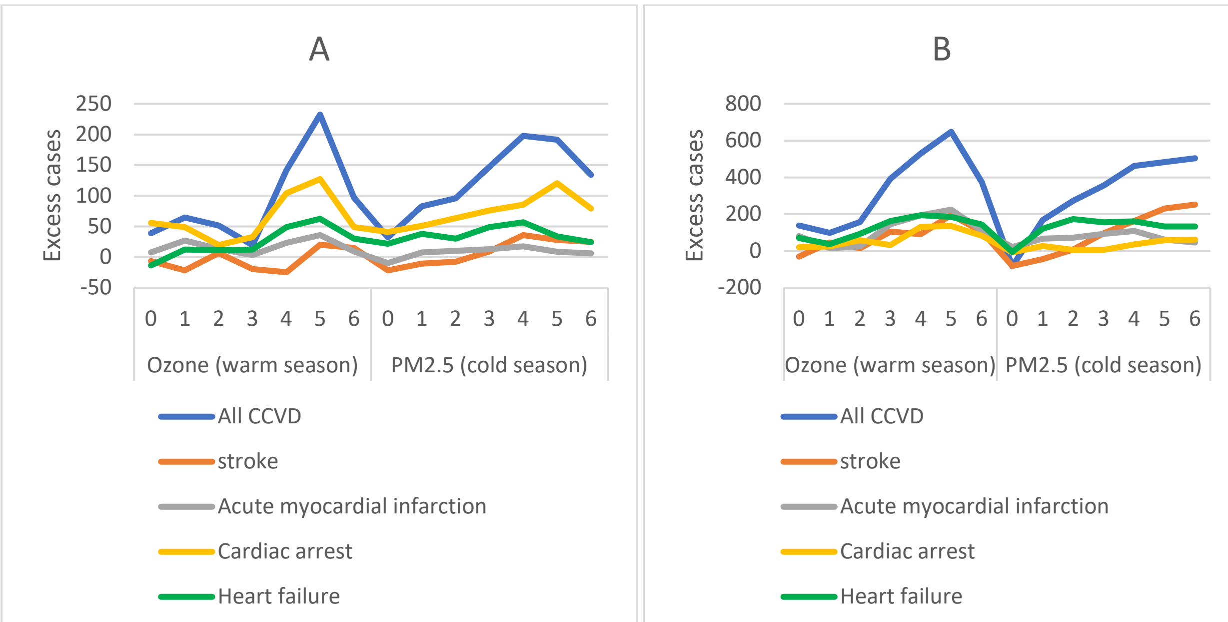
		OR (95% CI)[a]					
Pollutants	**Lag[b]**	**Non-Hispanic White**	**Non-Hispanic Black**	**Hispanic**	**Asian/PI**	**American Indian/Alaskan Native**	**Other**
Cold season $PM_{2.5}$	**0**	1.00 (0.99,1.01)	1.02 (0.98,1.05)	1.00 (0.98,1.01)	1.00 (0.97,1.03)	0.91 (0.78,1.08)	1.00 (0.94,1.07)
	1	1.01 (0.99,1.02)	1.01 (0.98,1.04)	1.00 (0.99,1.02)	1.01 (0.99,1.04)	1.03 (0.90,1.17)	0.98 (0.92,1.03)
	2	1.01 (0.99,1.02)	1.02 (0.98,1.05)	1.01 (0.99,1.03)	**1.03 (1.00,1.05)**	0.96 (0.84,1.10)	0.99 (0.94,1.05)
	3	1.01 (1.00,1.02)	1.00 (0.97,1.03)	**1.02 (1.00,1.04)**	**1.04 (1.01,1.06)**	0.95 (0.83,1.09)	1.03 (0.98,1.09)
	4	**1.02 (.001,1.03)**	1.00 (0.96,1.03)	1.02 (1.00,1.03)	**1.06 (1.04,1.09)**	0.96 (0.84,1.09)	1.04 (0.98,1.10)
	5	1.01 (1.00,1.03)	1.01 (0.98,1.05)	1.02 (1.00,1.03)	**1.05 (1.03,1.08)**	0.94 (0.83,1.07)	1.01 (0.95,1.06)
	6	**1.01 (1.00,1.02)**	0.98 (0.95,1.02)	**1.02 (1.00,1.04)**	**1.05 (1.03,1.08)**	1.01 (0.90,1.14)	0.99 (0.94,1.05)
Warm season ozone	**0**	1.01 (0.99,1.03)	1.04 (0.99,1.09)	0.99 (0.97,1.01)	0.99 (0.96,1.03)	0.91 (0.73,1.13)	0.97 (0.88,1.06)
	1	0.99 (0.98,1.01)	1.01 (0.97,1.05)	0.99 (0.97,1.01)	1.00 (0.97,1.04)	1.00 (0.81,1.22)	1.07 (0.99,1.15)
	2	0.99 (0.97,1.00)	1.00 (0.96,1.04)	1.00 (0.98,1.02)	0.97 (0.94,1.01)	0.98 (0.80,1.20)	1.04 (0.97,1.12)
	3	1.00 (0.99,1.02)	1.00 (0.96,1.04)	1.01 (0.99,1.03)	1.00 (0.97,1.04)	0.99 (0.81,1.21)	1.05 (0.98,1.14)
	4	1.00 (0.99,1.02)	0.98 (0.94,1.02)	1.01 (0.99,1.04)	1.03 (0.99,1.06)	1.08 (0.87,1.33)	1.08 (1.00,1.16)
	5	1.00 (0.99,1.02)	0.97 (0.93,1.01)	**1.05 (1.03,1.07)**	1.00 (0.97,1.04)	0.96 (0.79,1.16)	1.02 (0.94,1.10)
	6	1.01 (0.99,1.02)	1.00 (0.96,1.04)	1.02 (0.99,1.04)	0.99 (0.96,1.02)	0.84 (0.69,1.01)	1.00 (0.93,1.08)

[a]Models adjusted for temperature, humidity, and co-pollutants. Time-unvarying factors were controlled by study design. Estimates were obtained for each 5-unit increase in pollutants. Cold season: Nov. – Apr., warm season: May-Oct.
[b]Lag can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc. Abbreviations: $PM_{2.5}$, particulate matter <2.5 microns; OR, odds ration; CI, confidence intervals. Boldface font indicates statistical significance at p<0.05.

3.3.3 EXCESS CARDIO-CEREBRAL VASCULAR EVENTS ASSOCIATED WITH AIR POLLUTION.

During the study period, each additional 5-unit increase in ozone resulted in up to 232 cases of ED visits and almost 600 hospitalizations due to CCVD (**Figure 3.8, Table 3.8**). Similarly, $PM_{2.5}$ exposures resulted in approximately 200 ED visits and more than 500 hospitalizations. Analyses by specific CCVD types showed a consistent pattern and are presented in **Figure 3.8** and **Table 3.8**.

Figure 3.8. Excess number of ED visits (A) and hospitalizations (B) associated with air pollution in Fresno during the study period



Estimates are for each 5-unit decrease in air pollution. Numbers on x-axis represent lag, which can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc.
Abbreviations: $PM_{2.5}$, particulate matter <2.5 microns; CCVD, cardio cerebral vascular disease.

Table 3.8. Excess CCVD cases associated with pollutants

Pollutants	Lag[a]	Excess cases per 10,000 people (95% CI) ED visits	Hospitalizations	Total excess cases during study period ED visits	Hospitalizations
			Any CCVD		
Ozone	0	0.71 (-1.42, 2.96)	2.52 (-1.08, 6.48)	38.74 (-77.48, 161.42)	137.47 (-58.91, 353.48)
	1	1.18 (-0.95, 3.31)	1.80 (-1.80, 5.76)	64.57 (-51.66, 180.80)	98.19 (-98.19, 314.21)
	2	0.95 (-1.18, 3.08)	2.88 (-1.08, 6.48)	51.66 (-64.57, 167.88)	157.10 (-58.91, 353.48)
	3	0.36 (-1.78, 2.60)	7.20 (3.24, 11.16)	19.37 (-96.85, 142.05)	392.76 (176.74, 608.78)
	4	2.60 (0.47, 4.73)	9.72 (5.76, 13.68)	142.05 (25.83, 258.28)	530.23 (314.21, 746.24)
	5	4.26 (2.01, 6.51)	11.88 (7.92, 15.84)	232.45 (109.77, 355.14)	648.05 (432.04, 864.07)
	6	1.78 (-0.47, 3.91)	6.84 (2.88, 10.44)	96.85 (-25.83, 213.08)	373.12 (157.10, 569.50)
$PM_{2.5}$	0	0.59 (-1.05, 2.11)	-1.54 (-4.23, 1.15)	31.92 (-57.46, 114.93)	-83.88 (-230.66, 62.91)
	1	1.52 (-0.12, 3.04)	3.07 (0.38, 5.77)	83.00 (-6.38, 166.01)	167.75 (20.97, 314.53)
	2	1.76 (0.12, 3.28)	5.00 (2.31, 7.69)	95.77 (6.38, 178.78)	272.60 (125.81, 419.38)
	3	2.69 (1.05, 4.21)	6.53 (3.46, 9.22)	146.86 (57.46, 229.86)	356.47 (188.72, 503.26)
	4	3.63 (1.99, 5.15)	8.46 (5.77, 11.15)	197.93 (108.55, 280.94)	461.32 (314.53, 608.10)
	5	3.51 (1.87, 5.03)	8.84 (5.77, 11.53)	191.55 (102.16, 274.55)	482.29 (314.53, 629.07)
	6	2.46 (0.94, 3.98)	9.22 (6.53, 11.91)	134.09 (51.08, 217.09)	503.26 (356.47, 650.04)

Pollutants	Lag[a]	Excess cases per 10,000 people (95% CI) ED visits	Hospitalizations	Total excess cases during study period ED visits	Hospitalizations
		Stroke			
Ozone	0	-0.12 (-1.18, 0.97)	-0.55 (-2.89, 1.79)	-6.61 (-64.47, 52.90)	-30.08 (-157.90, 97.75)
	1	-0.39 (-1.42, 0.67)	0.83 (-1.52, 3.31)	-21.49 (-77.69, 36.37)	45.11 (-82.71, 180.46)
	2	0.12 (-0.94, 1.24)	0.28 (-2.07, 2.62)	6.61 (-51.24, 67.77)	15.04 (-112.79, 142.86)
	3	-0.36 (-1.42, 0.73)	1.93 (-0.41, 4.27)	-19.84 (-77.69, 39.67)	105.27 (-22.56, 233.09)
	4	-0.45 (-1.51, 0.61)	1.65 (-0.69, 4.00)	-24.80 (-82.65, 33.06)	90.23 (-37.60, 218.05)
	5	0.36 (-0.70, 1.48)	3.58 (1.24, 6.06)	19.84 (-38.02, 81.00)	195.49 (67.67, 330.84)
	6	0.27 (-0.79, 1.39)	1.93 (-0.41, 4.27)	14.88 (-42.98, 76.04)	105.27 (-22.56, 233.09)
$PM_{2.5}$	0	-0.40 (-1.14, 0.37)	-1.49 (-3.13, 0.14)	-21.78 (-62.24, 20.23)	-81.55 (-170.52, 7.41)
	1	-0.20 (-0.94, 0.57)	-0.82 (-2.58, 0.82)	-10.89 (-51.35, 31.12)	-44.48 (-140.87, 44.48)
	2	-0.14 (-0.88, 0.66)	0.14 (-1.49, 1.90)	-7.78 (-48.24, 35.79)	7.41 (-81.55, 103.80)
	3	0.17 (-0.57, 0.97)	1.77 (0.14, 3.53)	9.34 (-31.12, 52.90)	96.38 (7.41, 192.76)
	4	0.66 (-0.11, 1.45)	2.99 (1.22, 4.62)	35.79 (-6.22, 79.36)	163.11 (66.73, 252.08)
	5	0.51 (-0.29, 1.31)	4.21 (2.45, 5.98)	28.01 (-15.56, 71.58)	229.83 (133.45, 326.22)
	6	0.46 (-0.29, 1.23)	4.62 (2.99, 6.39)	24.90 (-15.56, 66.91)	252.08 (163.11, 348.46)
		Acute myocardial infarction			
Ozone	0	0.14 (-0.33, 0.65)	1.46 (-0.46, 3.47)	7.70 (-17.76, 35.22)	79.78 (-24.93, 189.47)
	1	0.49 (-0.02, 1.05)	0.27 (-1.65, 2.19)	26.64 (-1.18, 57.13)	14.96 (-89.75, 119.66)
	2	0.24 (-0.24, 0.77)	0.46 (-1.46, 2.38)	13.02 (-13.32, 41.74)	24.93 (-79.78, 129.64)
	3	0.06 (-0.40, 0.56)	2.65 (0.73, 4.66)	3.26 (-21.90, 30.49)	144.59 (39.89, 254.29)
	4	0.42 (-0.08, 0.97)	3.56 (1.65, 5.57)	23.09 (-4.14, 52.98)	194.45 (89.75, 304.15)
	5	0.66 (0.13, 1.23)	4.11 (2.01, 6.12)	35.82 (7.10, 67.19)	224.37 (114.68, 334.06)
	6	0.16 (-0.30, 0.67)	2.01 (0.09, 4.02)	8.88 (-16.28, 36.41)	109.69 (4.99, 219.38)
$PM_{2.5}$	0	-0.18 (-0.52, 0.18)	0.38 (-1.04, 1.79)	-9.92 (-28.52, 9.61)	20.57 (-56.57, 97.72)
	1	0.14 (-0.21, 0.50)	1.23 (-0.19, 2.64)	7.44 (-11.47, 27.28)	66.86 (-10.29, 144.00)
	2	0.19 (-0.17, 0.56)	1.32 (-0.09, 2.83)	10.23 (-9.30, 30.69)	72.00 (-5.14, 154.29)
	3	0.23 (-0.13, 0.61)	1.70 (0.28, 3.21)	12.71 (-7.13, 33.48)	92.57 (15.43, 174.86)
	4	0.32 (-0.04, 0.70)	1.98 (0.57, 3.39)	17.36 (-2.17, 38.13)	108.00 (30.86, 185.15)
	5	0.15 (-0.20, 0.53)	1.13 (-0.28, 2.55)	8.37 (-10.85, 28.83)	61.72 (-15.43, 138.86)
	6	0.11 (-0.23, 0.48)	0.85 (-0.57, 2.26)	6.20 (-12.40, 26.04)	46.29 (-30.86, 123.43)
		Cardiac arrest			
Ozone	0	1.02 (-0.48, 2.63)	0.37 (-1.01, 1.84)	55.44 (-26.09, 143.48)	20.09 (-55.24, 100.44)
	1	0.90 (-0.60, 2.51)	0.46 (-0.92, 1.93)	48.91 (-32.61, 136.96)	25.11 (-50.22, 105.46)
	2	0.36 (-1.14, 1.91)	1.06 (-0.37, 2.53)	19.57 (-61.96, 104.35)	57.75 (-20.09, 138.11)
	3	0.60 (-0.90, 2.21)	0.60 (-0.83, 2.03)	32.61 (-48.92, 120.66)	32.64 (-45.20, 110.48)
	4	1.91 (0.36, 3.47)	2.39 (0.87, 3.91)	104.35 (19.57, 189.14)	130.57 (47.71, 213.44)
	5	2.33 (0.72, 3.94)	2.49 (1.01, 4.00)	127.18 (39.13, 215.23)	135.59 (55.24, 218.46)
	6	0.90 (-0.66, 2.51)	1.52 (0.09, 2.99)	48.91 (-35.87, 136.96)	82.86 (5.02, 163.22)
$PM_{2.5}$	0	0.75 (-0.35, 1.86)	-0.15 (-1.12, 0.83)	41.16 (-19.00, 101.31)	-7.99 (-61.23, 45.25)
	1	0.93 (-0.17, 2.03)	0.49 (-0.49, 1.51)	50.66 (-9.50, 110.81)	26.62 (-26.62, 82.52)
	2	1.16 (0.06, 2.26)	0.10 (-0.83, 1.12)	63.32 (3.17, 123.47)	5.32 (-45.25, 61.23)
	3	1.39 (0.29, 2.50)	0.10 (-0.88, 1.07)	75.98 (15.83, 136.14)	5.32 (-47.92, 58.56)
	4	1.57 (0.46, 2.67)	0.63 (-0.39, 1.61)	85.48 (25.33, 145.64)	34.61 (-21.30, 87.85)
	5	2.21 (1.10, 3.31)	1.07 (0.10, 2.05)	120.31 (60.15, 180.46)	58.56 (5.32, 111.80)
	6	1.45 (0.41, 2.55)	1.12 (0.15, 2.10)	79.15 (22.16, 139.30)	61.23 (7.99, 114.47)
		Heart failure			
Ozone	0	-0.25 (-1.17, 0.71)	1.27 (-0.68, 3.22)	-13.72 (-63.60, 38.66)	69.33 (-36.98, 175.64)
	1	0.23 (-0.71, 1.23)	0.68 (-1.19, 2.71)	12.47 (-38.66, 67.34)	36.98 (-64.71, 147.90)
	2	0.21 (-0.71, 1.17)	1.69 (-0.25, 3.64)	11.22 (-38.66, 63.60)	92.44 (-13.87, 198.75)
	3	0.23 (-0.73, 1.23)	2.97 (1.02, 5.00)	12.47 (-39.90, 67.34)	161.77 (55.46, 272.70)
	4	0.89 (-0.11, 1.92)	3.56 (1.52, 5.59)	48.63 (-6.23, 104.75)	194.12 (83.20, 305.05)
	5	1.14 (0.16, 2.19)	3.39 (1.36, 5.51)	62.35 (8.73, 119.71)	184.88 (73.95, 300.43)
	6	0.55 (-0.41, 1.58)	2.63 (0.59, 4.66)	29.93 (-22.45, 86.04)	143.28 (32.35, 254.21)
$PM_{2.5}$	0	0.40 (-0.32, 1.14)	-0.11 (-1.58, 1.26)	21.65 (-17.59, 62.24)	-5.75 (-86.25, 69.00)

Pollutants	Lag[a]	Excess cases per 10,000 people (95% CI)		Total excess cases during study period	
		ED visits	Hospitalizations	ED visits	Hospitalizations
	1	0.69 (-0.05, 1.46)	2.21 (0.74, 3.69)	37.88 (-2.71, 79.83)	120.75 (40.25, 201.25)
	2	0.55 (-0.20, 1.29)	3.16 (1.79, 4.64)	29.77 (-10.82, 70.36)	172.50 (97.75, 253.00)
	3	0.89 (0.15, 1.61)	2.85 (1.37, 4.32)	48.71 (8.12, 87.95)	155.25 (74.75, 235.75)
	4	1.04 (0.30, 1.79)	2.95 (1.58, 4.43)	56.83 (16.24, 97.42)	161.00 (86.25, 241.50)
	5	0.62 (-0.10, 1.34)	2.42 (1.05, 3.90)	33.82 (-5.41, 73.06)	132.25 (57.50, 212.75)
	6	0.45 (-0.25, 1.19)	2.42 (1.05, 3.90)	24.35 (-13.53, 64.94)	132.25 (57.50, 212.75)

[a]Lag can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one

[a]Lag can be interpreted as the number of days after exposure. For example, lag 0 = risk on the day of exposure, lag 1 = risk one day after exposure, etc.

Estimates are for each 5-unit decrease in air pollution.

Abbreviations: $PM_{2.5}$, particulate matter <2.5 microns; CCVD, cardio cerebral vascular disease; ED, emergency department; OR, odds ratio; CI, confidence intervals.

3.4 SUMMARY

In our analyses of all ED visits and hospitalizations in Fresno between 2011 and 2020, we consistently found that both $PM_{2.5}$ and ozone were associated with increased risks of CCVD events within one week of exposure. Effects of ozone were observed primarily in the warm season and those of $PM_{2.5}$ were observed primarily in the cold season. Data further showed that pollution affects residents within and outside of the South Fresno AB 617 community boundaries differently. More specifically, the effects of $PM_{2.5}$ were more immediate and stronger for residents within the boundaries and effects of ozone were only present for those within the boundaries. Meanwhile, racial/ethnic disparities were also present, showing that communities of color are more impacted by air pollution, even at the same level of exposure. Consistent with findings in **Chapter 2**, given differences in impacts across geographic area and demographics characteristics such as race/ethnicity, we expect that the impacts of basin air pollution in the Fresno area may not be uniform for all residents, making efforts to reduce air pollution exposures among those who are more impacted even more critical.

Our findings are consistent with existing literature around the world. A recent systematic review and meta-analysis of almost 60 studies in different parts of the globe suggests that short-term exposures to $PM_{2.5}$ were consistently associated with increased risks of hypertension and triggering of myocardial infarction and stroke.[71] Another pertinent literature also suggests that air pollution, particularly fine particles, was associated with the risk of many CCVD conditions including myocardial infarction and heart failure.[76] A recent time series analysis also showed short-term exposures to ozone may also increase risks of being hospitalized for acute myocardial infarction, heart failure, and stroke.[70]

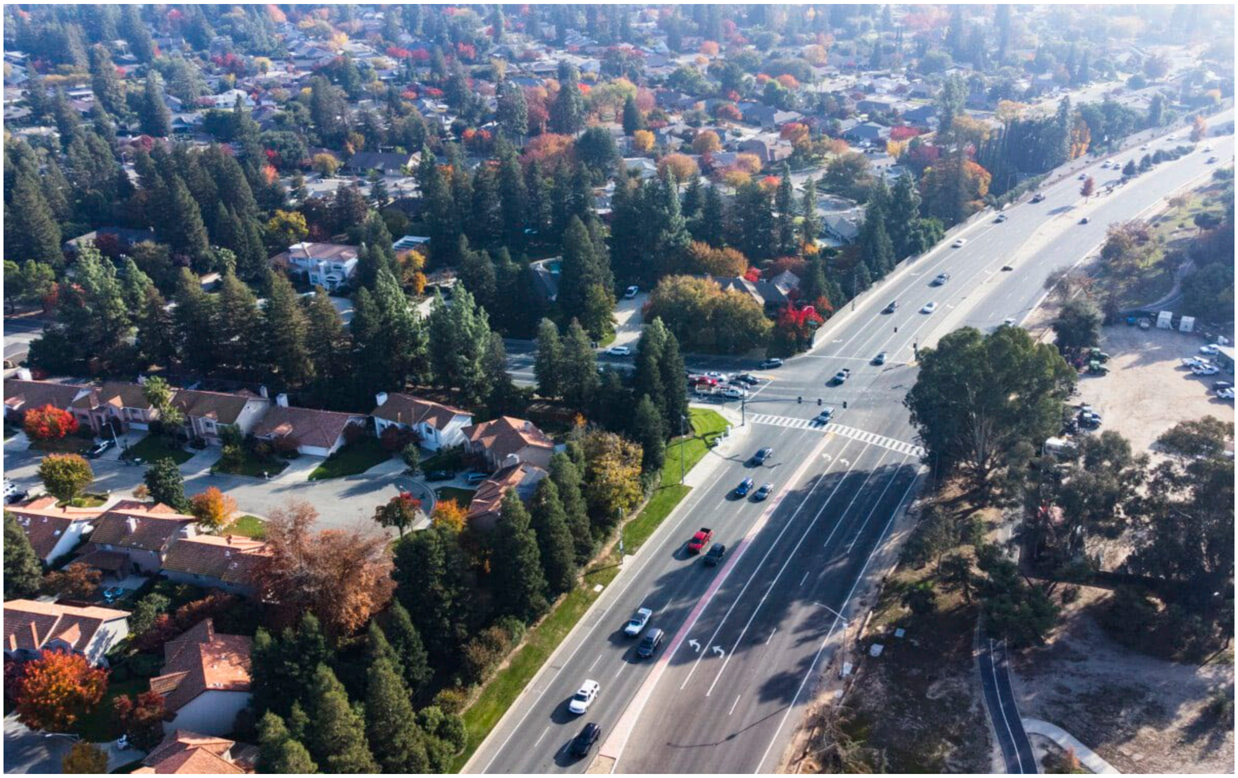
The disparities we observed have important implications for the health of Fresno residents, especially those who may be concurrently facing other stressors. Many recent epidemiologic studies consistently show higher adverse cardiovascular outcomes resulting from exposures to both short- and long-term air pollution among racial/ethnic minorities, those with lower socioeconomic positions, and those who are burdened by other stressors such as co-morbidities, stress, and other environmental burdens.[77,78] These additional health burdens can exacerbate the impacts of air pollution.

3.5 RECOMMENDATIONS

Based on the findings in this chapter, our recommendations are as follows:

1. Previously mentioned recommendations to reduce air pollution (through a 1,000 foot-buffer for truck traffic) should be adhered to and strengthened in Fresno.
2. Such efforts should also consider vulnerable populations, which include those living within the South Fresno AB 617 community boundaries and racial/ethnic minorities.
3. We also recommend the use of zero-emission commercial trucks when possible to minimize population exposure

CHAPTER 4. COMMUNITY-BASED HEALTH SURVEY IN SOUTH FRESNO AB 617 COMMUNITIES



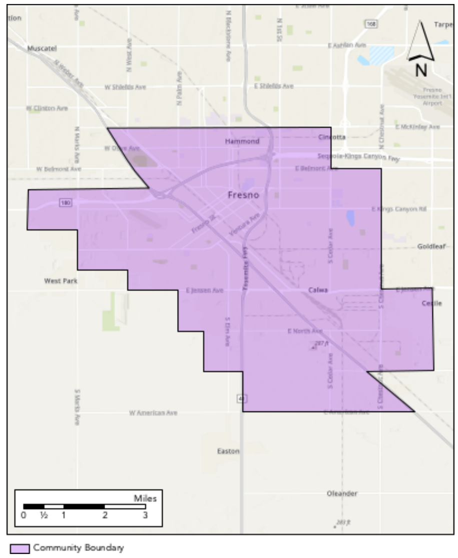
4.1 BACKGROUND

While population-based health data presented in Chapters 1 through Chapter 3 are critical and provide a comprehensive way to assess the health of populations, we also value the concerns and needs from residents of South Fresno. Such data are not available in population datasets, necessitating new data collection. Working closely with multiple community partners, the city, and the Air District, we sought to hear from residents in one of the most polluted areas in Fresno regarding their environmental health concerns, health needs, civic engagement, and policy preferences towards environmental issues.

4.2 METHODS

The study took place within the South Fresno area (**Figure 4.1**). We obtained all residential addresses (without identifiable information) from the region from the City of Fresno GIS Hub.[79] To ensure representativeness of the data, we randomly selected addresses within the study area. Centrally trained researchers went to the selected addresses to administer an approximately 15-minute survey, which asked about demographics, environmental health concerns, health needs, civic engagement, and policy preferences towards environmental issues. The survey took place from February to June, 2023, and was conducted in either English or Spanish.

Figure 4.1. Survey area



Source: California Air Resources Board

Our survey instrument was developed with several rounds of input from the SJV Air District, the Community Steering Committee, and community-based organization partners. We also obtained feedback during early surveys to improve our survey questionnaire.

To be eligible for the study, we selected the head of the household or significant other who was a) at least 18 years old, b) lived in the study area for at least one year, and c) speaks Spanish or English. A total of 1,766 residents participated in our survey. Although the survey is a random sample, we performed post-hoc weighting by age and race/ethnicity to optimize data generalizability. More specifically, we obtained five-year estimates (2017-2021) from the Census Bureau's American Community Survey (ACS) Public Use Microdata Sample (PUMS) data.[64] The PUMS contains records about a representative of individual people or housing units within specific regions of the U.S. From this data, we obtained information about individuals living within the study area and determined their demographic characteristics. These estimates represent known characteristics of the study area. We then used these estimates to create weights for our study sample to ensure it is representative of the rest of the population living in the study region.

Table 4.1 below shows that our study sample is very similar to the population characteristics of the study area, especially after weighting.

The study was approved by the UC Merced Institutional Review Board. All analyses were done in SAS 9.2 (Cary, NC) and Microsoft Excel.

Table 4.1. Comparison of study sample and target population

Demographics	Survey sample		Target population
	N (%)	N (weighted %)	N (%)[a]
Age (years)			
18-34	516 (30)	38.0	37.8
35-54	669 (38.8)	33.8	33.6
55-74	483 (28)	23.1	23.0
75+	57 (3.3)	5.1	5.6
Sex (n, %)			
Female	923 (52.3)	51.8	49.3
Male	834 (47.3)	47.6	50.7
Not disclosed	8 (0.5)		
Race/ethnicity (n, %)			
White	243 (15.3)	21.0	20.9
Black	272 (17.1)	5.5	5.5
Hispanic	817 (51.4)	60.3	60.0
Asian/Pacific Islanders	41 (2.6)	10.5	11.0
Native American/Alaskan	28 (1.8)	0.5	0.5
Multirace	151 (9.5)	1.8	1.8
Other	36 (2.3)	0.3	0.3
Education less than high school (n,%)	477 (27.5)	26.8	27.8
Did not work last week (n,%)	523 (34.8)	37.4	38.4

[a]Data were estimated from the Public Use Micro Sample data (2017-2021) from the US census.

We were able to geocode 1,140 participants (65%) who gave us permission to use their addresses. Addresses were linked to the nearest warehouse or distribution center, truck route, freeway, or major road, and distances were calculated. Given the small sample size and the rarity of some of the health outcomes, we were not able to run complex statistical models. Thus, we present descriptive statistics illustrating the risks of having any chronic condition or adverse pregnancy outcome, comparing people within and outside a 1,000 feet buffer from the various sources. Other buffers were also considered, but 1,000 feet appeared to be the distance that best distinguishes the risks inside and outside, consistent with our analyses in Chapter 1.

4.3 RESULTS

4.3.1 STUDY PARTICIPANTS

A total of 1,766 residents participated in our survey. **Table 4.2** describes participants' characteristics. The modal responses for survey participants were age 18-34 (37.9%), Hispanic/Latino (60.2%), high school graduates (38.6%), never married (50.7%), and had personal wage and salary income of 10-25K/year (among those employed at the time of the survey).

Table 4.2. Characteristics of survey participants (n=1,766)

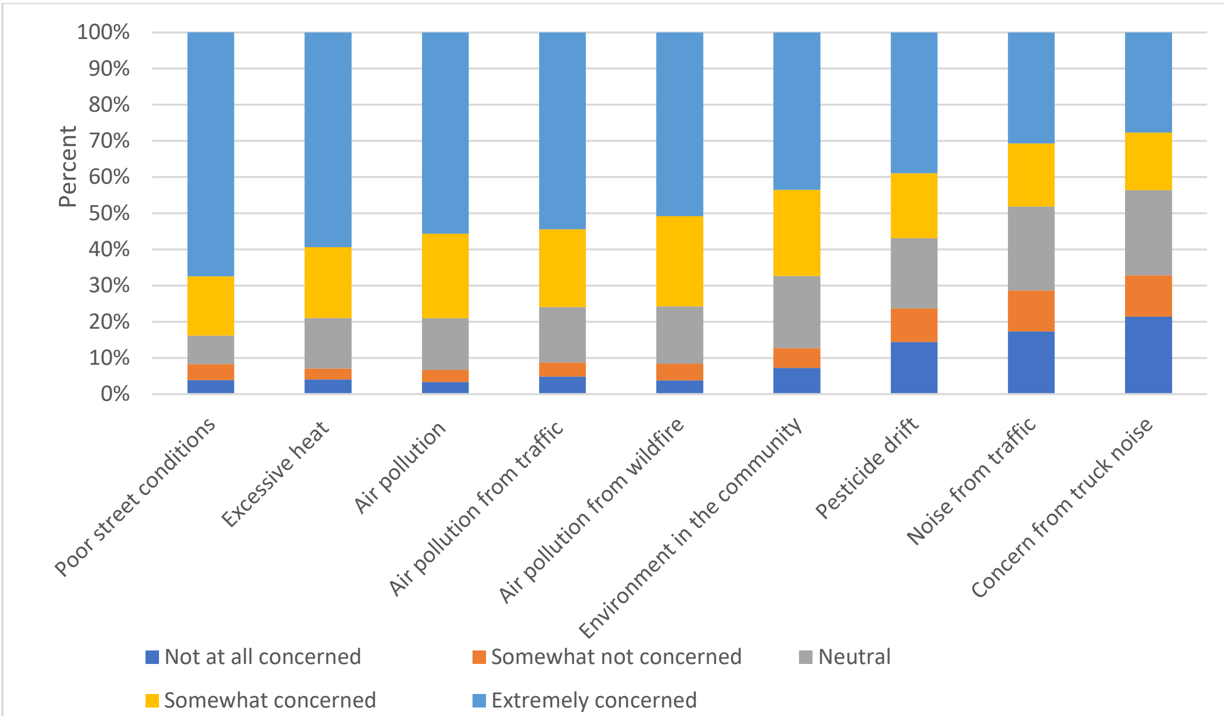
Characteristics	n	Weighted %
Age (years)		
18-34	516	38.0
35-54	669	33.8
55-74	483	23.1
75+	57	5.1
Sex		
Female	923	51.8
Male	834	47.6
Prefer to not disclose	8	0.5
Race/ethnicity		
White	243	21.0
Black	272	5.5
Asian/Native Hawaiian/ Pacific Islander	41	10.6
Native American/Alaskan	28	0.5
Hispanic/Latino	817	60.3
Two or more races	151	1.8
Other	10	0.3
Education		
Less than high school	477	26.8
High school	674	38.6
Some college	442	25.4
College graduate or more	144	9.2
Marital status		
Never married	913	50.7
Married	649	38.0
Divorced/Widowed	192	11.3
Income[a]		
$0-$9,999	568	24.2
$10,000-$24,999	235	33.2
$25,000-$49,999	176	24.7
$50,000-$74,999	57	10.1
>$75,000	39	7.9
Don’t know/Refused	220	-
Missing	471	-

[a]Percent was only calculated among those employed at the time of the survey.

4.3.2 RESIDENTS’ ENVIRONMENTAL HEALTH CONCERNS

When residents were asked to rate their concerns with respect to environmental issues in their community, the majority (~70%) responded that they were somewhat concerned or extremely concerned with the general environment in their community (**Figure 4.2**). When asked about specific issues, the majority reported that poor street conditions (84%), general air pollution (79%), excessive heat (79%), wildfire pollution (76%), and traffic pollution (76%) were top concerns. Meanwhile, almost half the participants reported concerns regarding traffic noise and truck noise. These estimates were weighted to maximize generalizability.

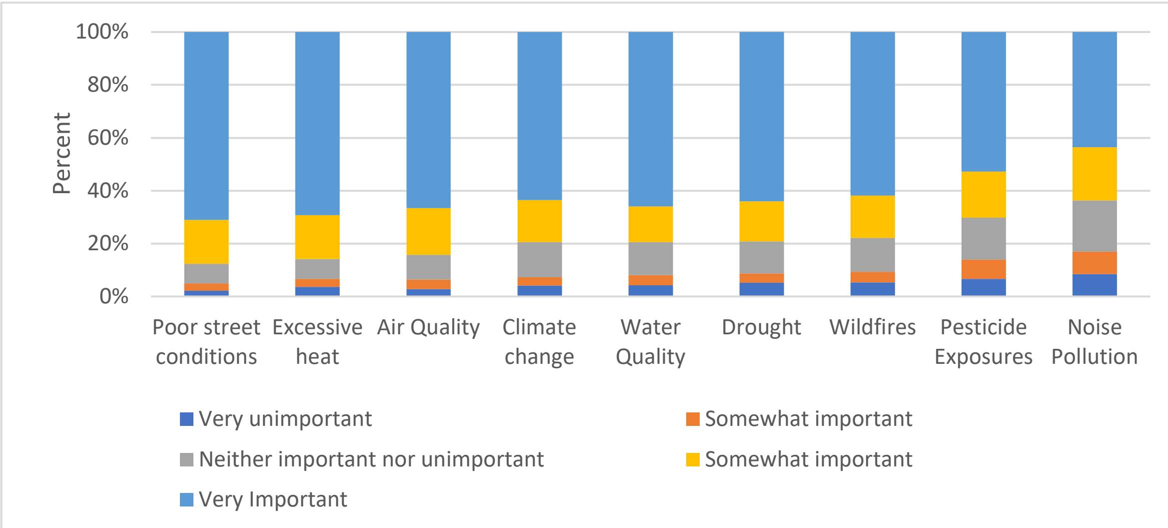
Figure 4.2. Residents' concerns about the environment in their community



Note: Estimates were weighted

Residents' responses to the question, "Considering your household and community needs, how important will it be for the government to address the following environmental issues within the next few years?" are presented in **Figure 4.3**. For all listed environmental issues, most respondents believed that addressing these issues is somewhat or very important. There was minimal variation between different issues, indicating a uniformly high level of concern across all environmental conditions. The top three environmental issues that residents would like the government to address in the next few years were poor street conditions (88%), excessive heat (86%), and air quality (84%). Very few respondents considered these environmental issues unimportant, underscoring the overall significance of environmental concerns among South Fresno residents.

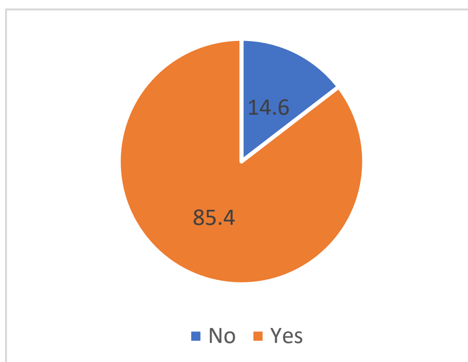
Figure 4.3. Importance of local government to address environmental issues within the next few years



Note: Estimates were weighted

Related to air quality, an overwhelming majority of residents (over 85%) stated that the government should invest public funds to build new roads that redirect truck traffic away from local streets (**Figure 4.4**).

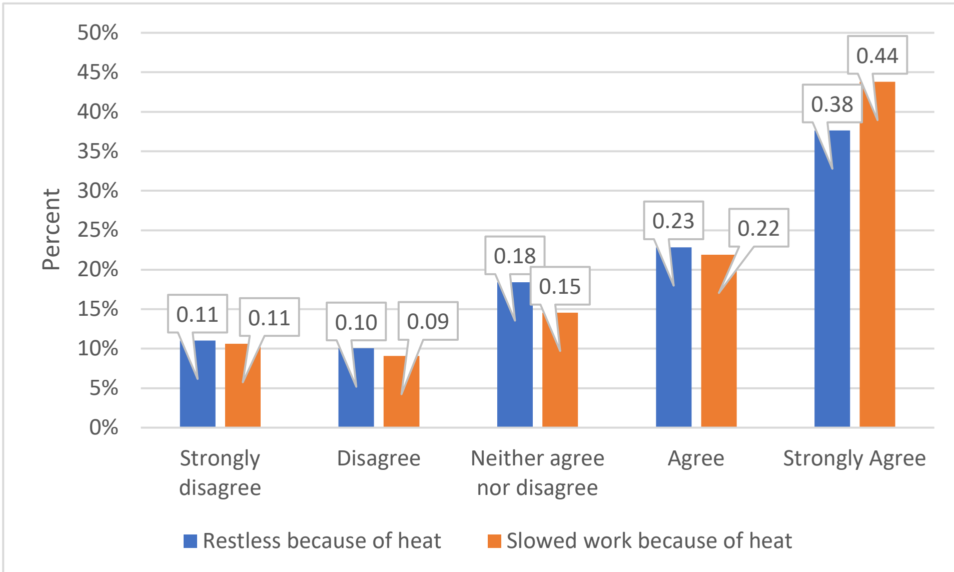
Figure 4.4. Residents' preference for new roads that direct truck traffic away from local streets



Note: Estimates were weighted

When asked about additional environmental health concerns, residents reported having problems resting or working because of either heat, air pollution, or traffic/truck noise. More specifically, with reference to the September 2022 heatwave, 66% agreed or strongly agreed that they had to slow work and 61% reported that they were unable to rest because of heat (**Figure 4.5**). Given the expected increase in the frequency, intensity, and duration of heat events, these findings warrant further investigation to ensure residents can rest properly and work comfortably during heat events.

Figure 4.5. Impacts of heat on rest and work

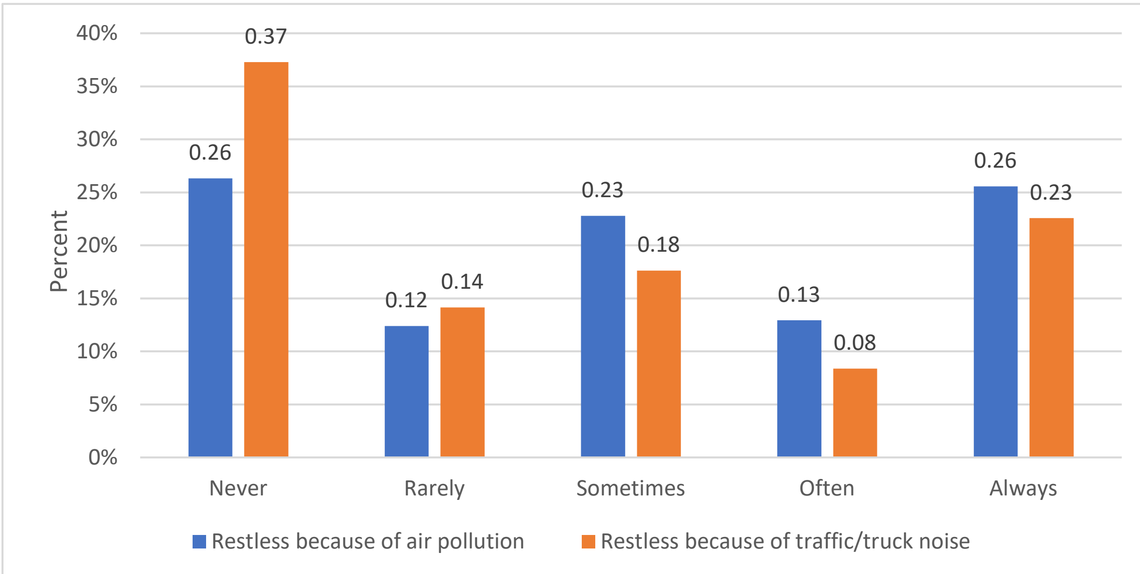


Note: Estimates were weighted

Furthermore, approximately 22.4% of participants reported that they use a community cooling center, and 28% said that they seek shelter somewhere else when the temperature is too high. This may mean that many residents may not have access to effective cooling, which may present health risks during heat events.

Almost half of the residents (49%) reported sometimes, often, or always being unable to rest because of traffic/truck noise. Meanwhile, 61% reported being unable to rest because of air pollution (**Figure 4.6**). These data suggest that air pollution and traffic noise are bothering residents significantly, and efforts to minimize exposure may be prudent.

Figure 4.6. Impacts of air pollution and traffic noise on home rest



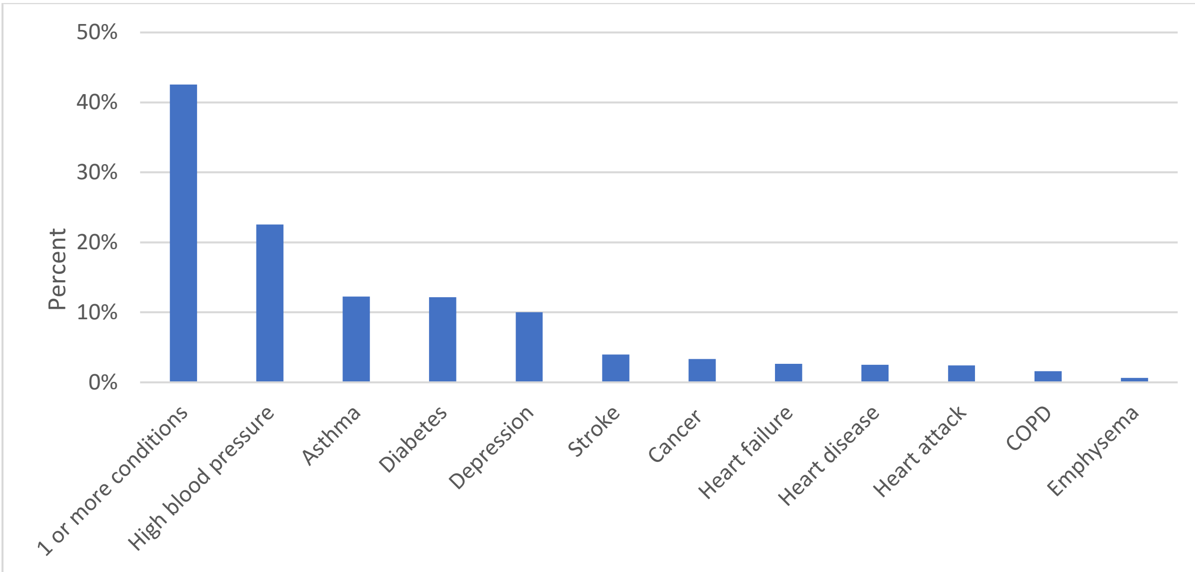
Note: Estimates were weighted

4.3.3 HEALTH CONDITIONS

CHRONIC HEALTH CONDITIONS

Approximately 43% of residents have been diagnosed with at least one chronic health ailment, including stroke, heart failure, heart attack, heart disease, high blood pressure, diabetes, cancer, asthma, emphysema, chronic obstructive pulmonary disease, or depression. The most commonly reported conditions among these are high blood pressure at 23%, followed by both diabetes and asthma at 12%, and depression at 10% (**Figure 4.7**). It is important to note that some of these health endpoints could be underreported because residents may not be aware they have them (e.g., high blood pressure, depression).

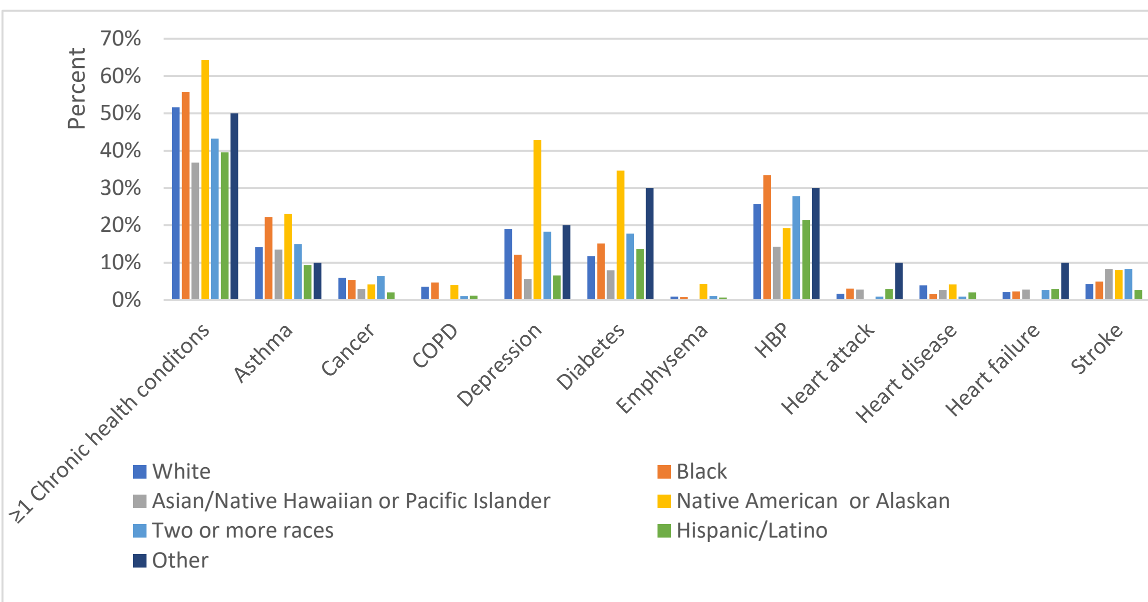
Figure 4.7. South Fresno Residents' chronic health conditions



Note: Estimates were weighted; abbreviations: COPD, chronic obstructive pulmonary disease.

When stratified by demographic characteristics, residents who are Native American/Alaskan were generally more likely to experience chronic health conditions compared to their counterparts (**Figure 4.8**). When analyzed by specific condition, this pattern is consistent for asthma, depression, and diabetes. Non-Hispanic Black residents had the highest prevalence of high blood pressure. Residents belonging to the "Other" category also reported higher prevalence of heart attack and heart failure.

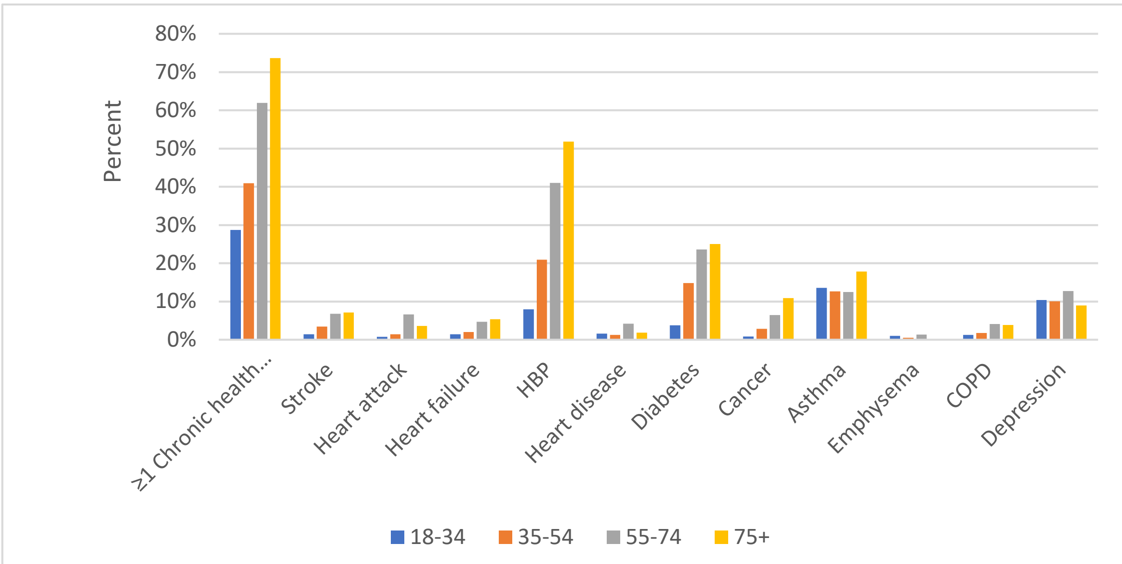
Figure 4.8. Self-reported health conditions by race/ethnicity



Abbreviations: COPD, chronic obstructive pulmonary disease; HBP, high blood pressure

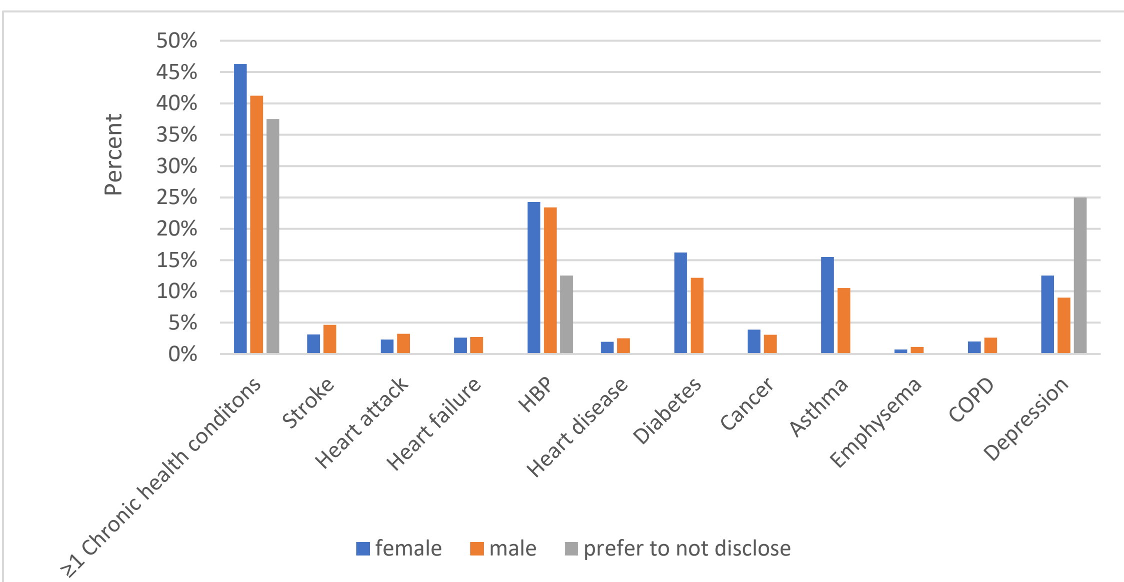
As expected, the prevalence of chronic health conditions increased with age (**Figure 4.9**). Female residents were more likely to report 1 or more chronic health conditions compared to male, but this pattern is reversed for some specific conditions (**Figure 4.10**). We did not observe meaningful differences in general prevalence across educational attainment, but these patterns varied by specific condition (**Figure 4.11**). Furthermore, residents with lower self-reported annual income generally had higher prevalence of having one or more chronic health conditions (**Figure 4.12**).

Figure 4.9. Self-reported chronic health conditions by age



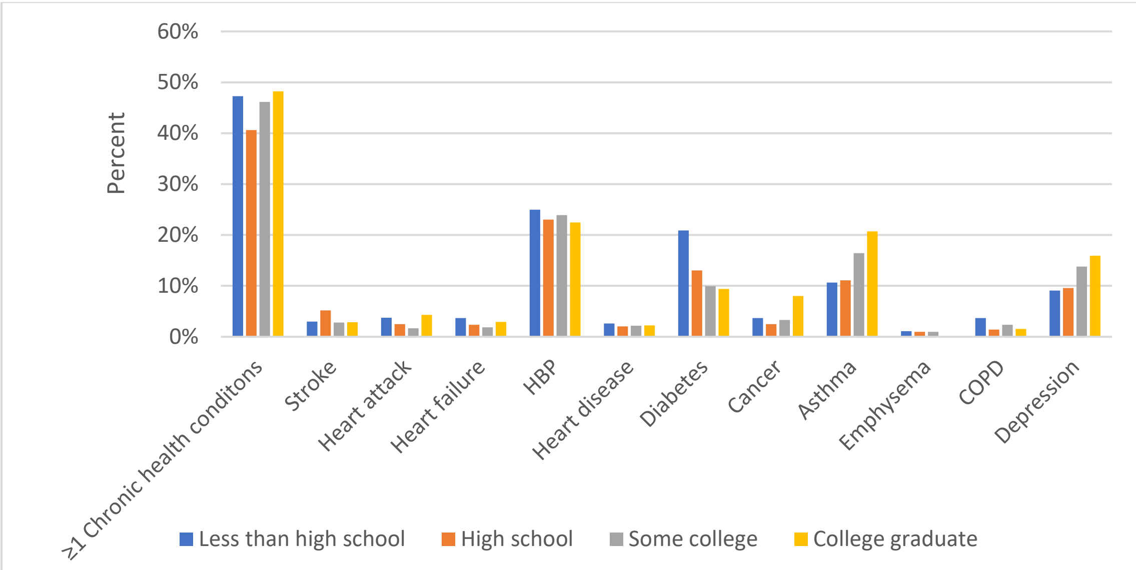
Abbreviations: COPD, chronic obstructive pulmonary disease; HBP, high blood pressure

Figure 4.10. Self-reported chronic health condition by sex



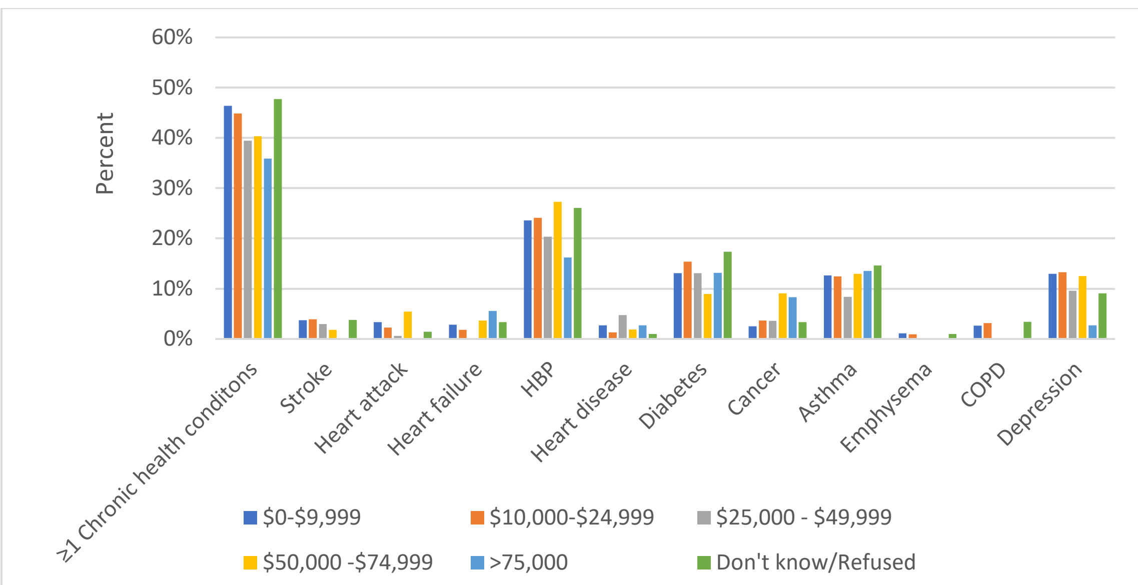
Abbreviations: COPD, chronic obstructive pulmonary disease; HBP, high blood pressure

Figure 4.11. Self-reported chronic health condition by educational attainment



Abbreviations: COPD, chronic obstructive pulmonary disease; HBP, high blood pressure

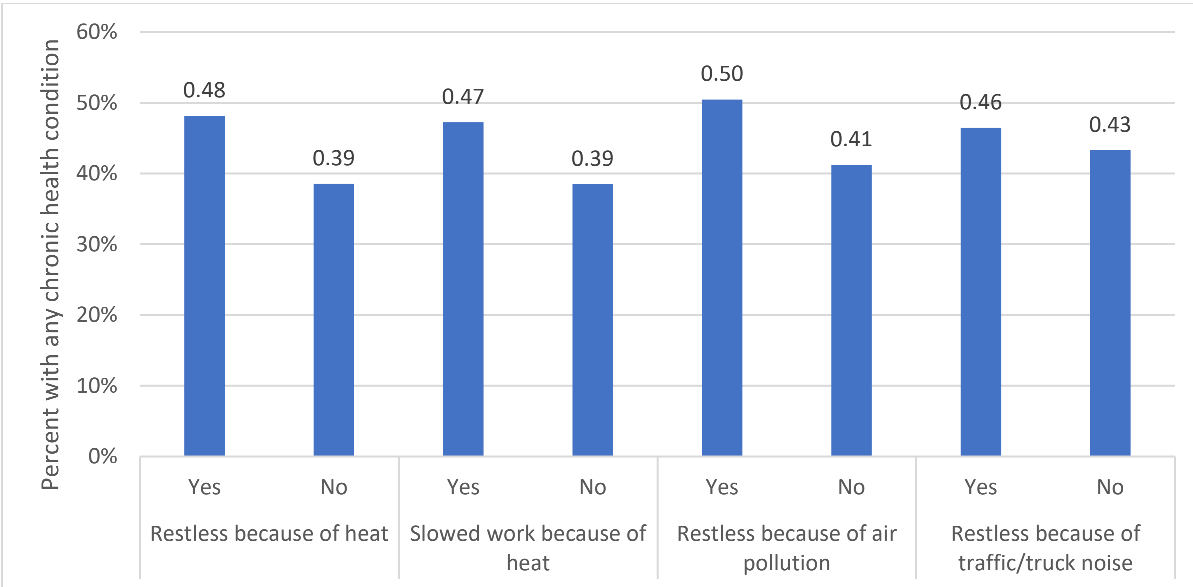
Figure 4.12. Self-reported chronic health condition by annual income



Abbreviations: COPD, chronic obstructive pulmonary disease; HBP, high blood pressure

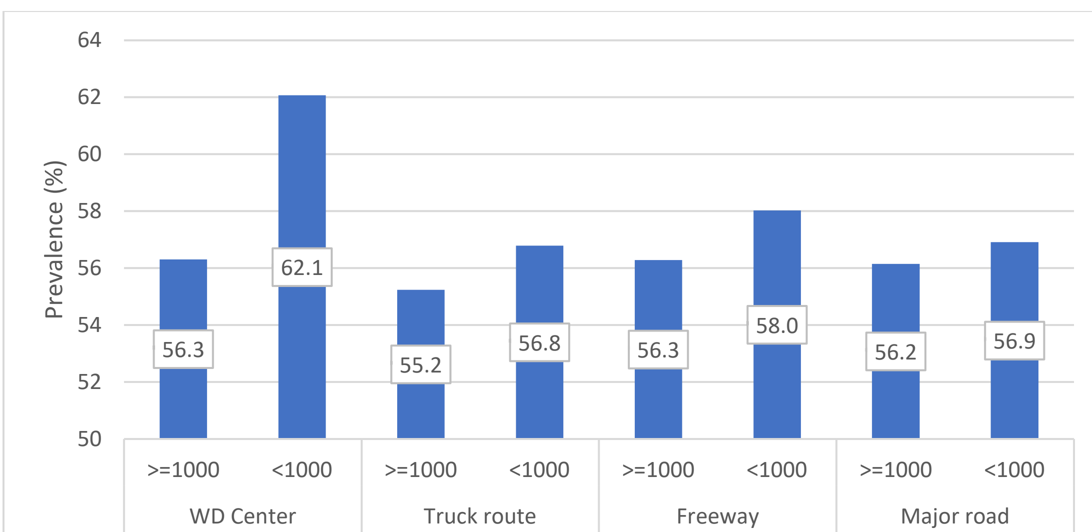
In general, the prevalence of having at least one chronic health condition was higher among residents who reported having to slow down work due to heat, air pollution, or truck/traffic noise (**Figures 4.13**).

Figure 4.13. Chronic health condition by environmental health concerns



Among participants with geocodable addresses, nearly 57% had one or more of the chronic health conditions listed above. In general, those who lived within 1,000 feet of a warehouse/distribution (WD) center, truck route, freeway, or major road appeared to have a higher prevalence of chronic health conditions (**Figure 4.14**). We note that these findings do not suggest that if we go outside of 1,000 feet, the risks will become insignificant. The buffer of 1,000 feet was chosen because it best distinguishes the risks outside and inside of the buffer.

Figure 4.14. Prevalence of having one or more chronic health conditions by proximity to pollution sources

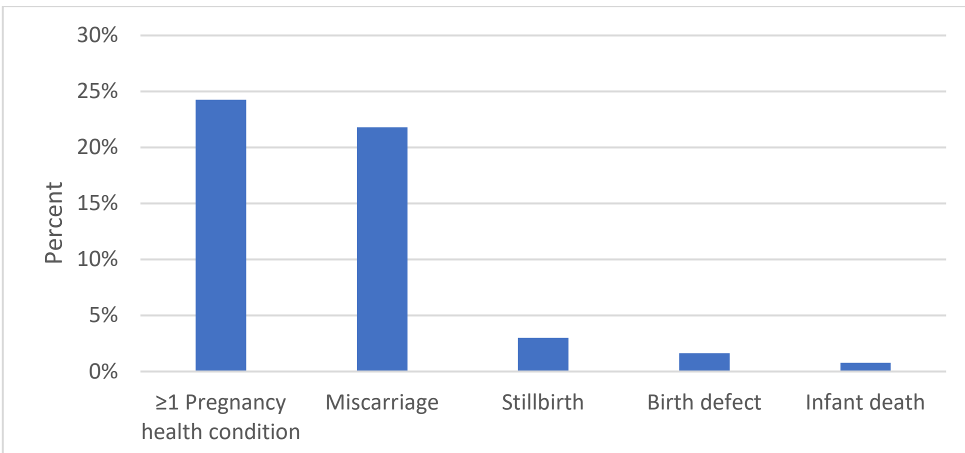


Abbreviation: WD, warehouse/distribution center

PREGNANCY OUTCOMES

Among reproductive-aged adult female respondents ages 18-46 years (n=541), about a quarter reported having at least one adverse pregnancy outcome including miscarriage, stillbirth, birth defects, or infant death. Twenty two percent (22%) reported having had a miscarriage and 3% reported stillbirth (**Figure 4.15**). Additionally, approximately 0.8% reported having a child who died within one year of life, and 1.6% reported having a child with a birth defect. We note that many of these estimates are high compared to the expected prevalence in the general population, but also recognize that these outcomes are rare and can contribute to unstable estimates in a relatively small survey.

Figure 4.15. Prevalence of selected pregnancy outcomes among reproductive-aged women



Reproductive age is defined as 18-46 years.

Adverse pregnancy outcomes varied by sociodemographic characteristics such as race/ethnicity, age, education, and income (**Figures 4.16 - 4.19)**. However, we also recognize that once restricted to only reproductive-age women, our sample became smaller and less stable, especially when some of the health outcomes were rare. In general, adverse pregnancy conditions were more common among Black women, especially stillbirths and infant death. These pregnancy outcomes were generally higher among women with higher maternal age, except for infant death, where younger women tended to have higher prevalence.

Figure 4.16. Adverse pregnancy outcomes by race/ethnicity

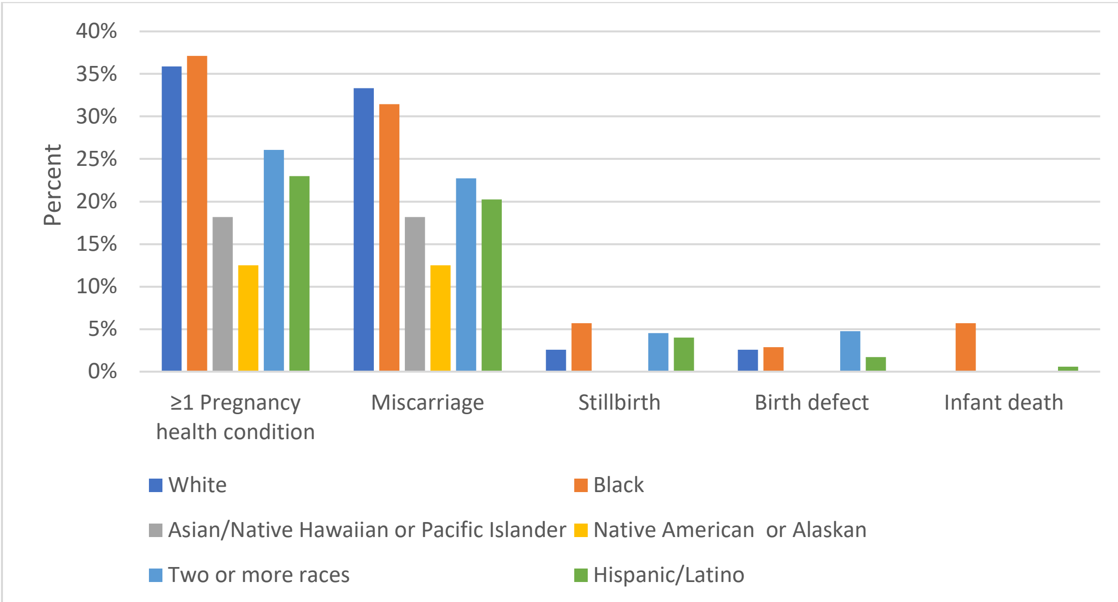


Figure 4.17. Adverse pregnancy outcome by maternal age

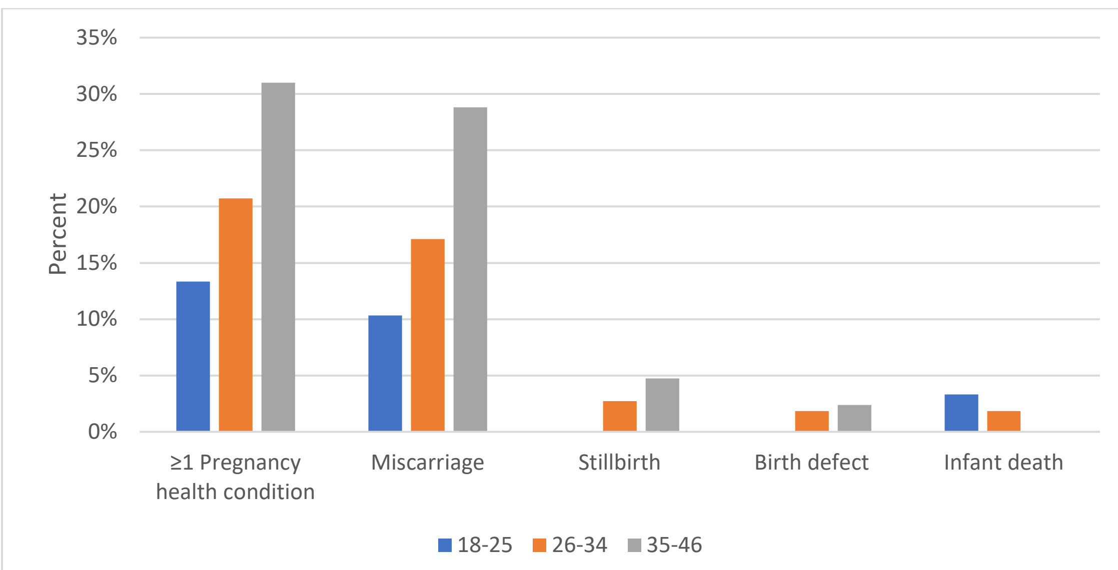


Figure 4.18. Adverse pregnancy outcomes by educational attainment

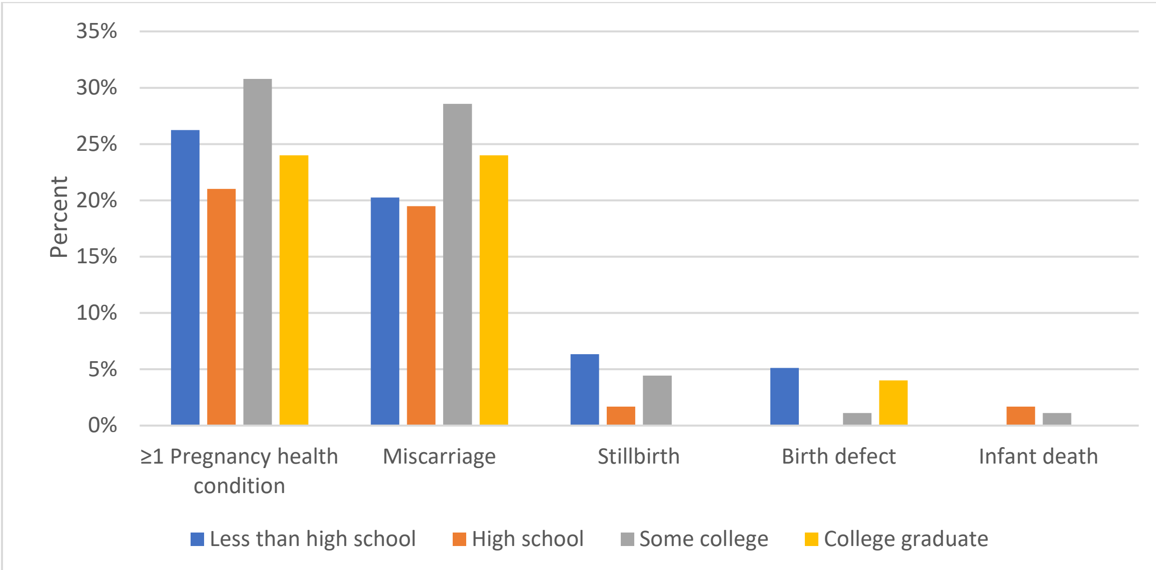
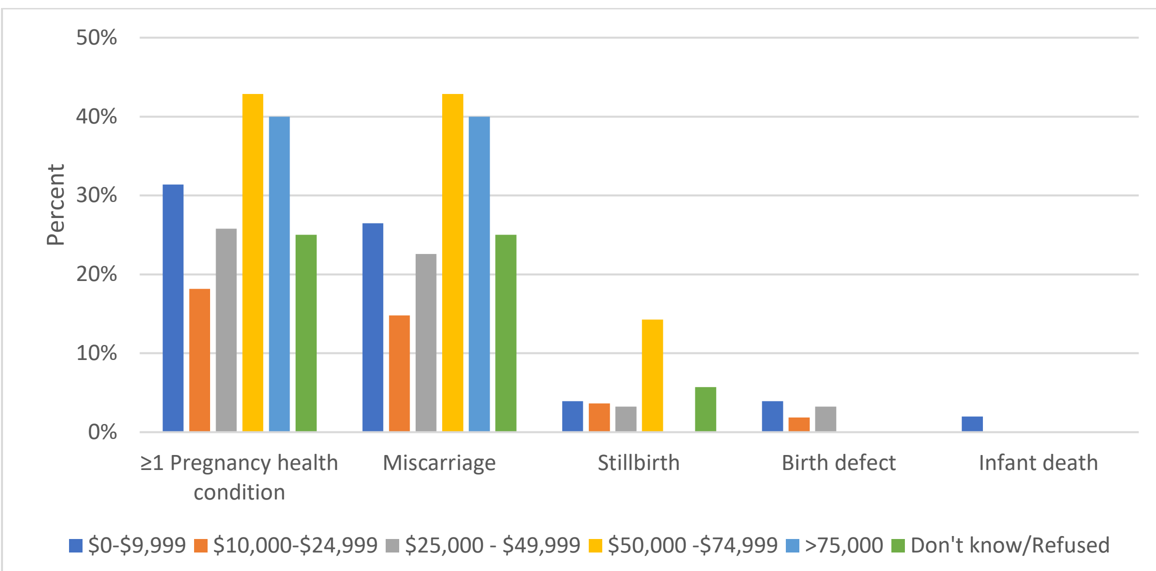


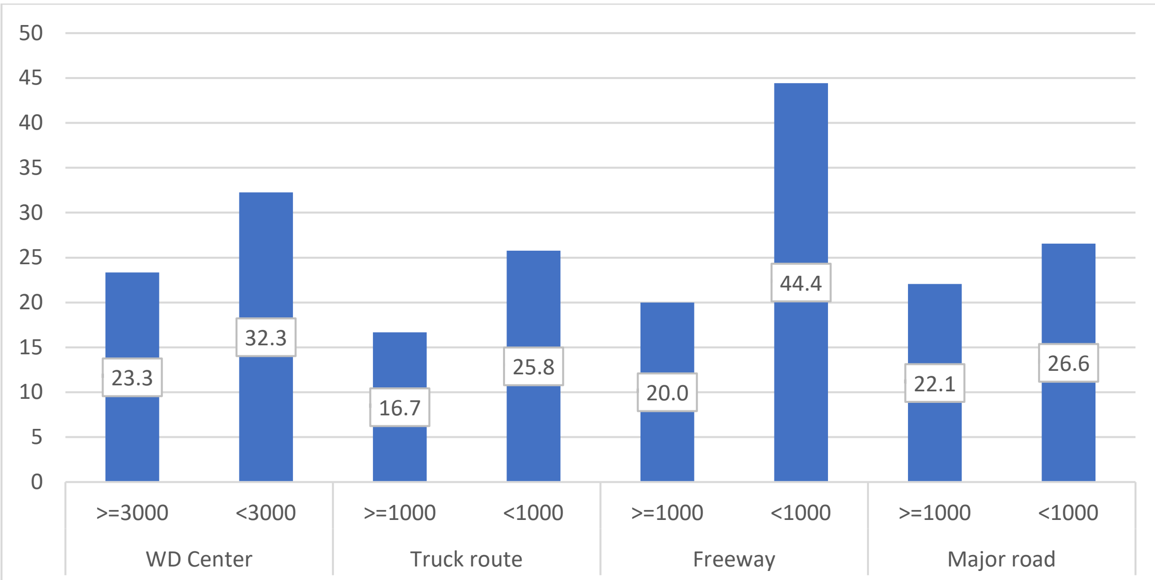
Figure 4.19. Adverse pregnancy outcomes by income



We did not observe a consistent pattern of correlation between adverse pregnancy outcomes and self-reported restlessness due to heat, pollution, or truck/traffic noise. However, we observed that people who reported restlessness due to air pollution or truck/traffic noise had a higher prevalence of stillbirth, birth defects, and infant death.

Among women of reproductive age who gave us permission to geocode their address (n=181), the prevalence of any adverse pregnancy outcomes (miscarriage, stillbirth, infant death, or birth defect) was 25%, similar to that of all reproductive age women in the survey. When stratified by proximity to various pollution sources, those who lived within 1,000 feet of a truck route, freeway, or major road had elevated prevalence compared to those who lived further away (**Figure 4.20**). We note that these findings do not suggest that if we go outside of 1,000 feet, the risks of adverse pregnancy outcomes will become negligible. The buffer of 1,000 feet was chosen because it best distinguishes the risks outside and inside of the buffer. Although proximity to warehouse/distribution centers was not related to risk at 1,000 feet due to small data sample, we observed increased risks for those who lived within 3000 feet of a warehouse or distribution center.

Figure 4.20. Prevalence of having any adverse pregnancy outcome by proximity to pollution sources



WD: warehouse or distribution center

4.3.4 CIVIC ENGAGEMENT

A significant proportion of residents reported that they are willing to attend local meetings to discuss issues related to truck traffic/air pollution (31%), and adaptation strategies to climate change (32%). In addition, 32% expressed interest in receiving information and invitations on air pollution, truck traffic, or local planning.

4.4 SUMMARY

In this representative survey sample of 1,766 South Fresno residents, we uncovered significant environmental health concerns in the community. More specifically, residents expressed high concerns regarding environmental issues such as poor street conditions, air quality, and climate change. Almost half of the residents surveyed (43%) reported having at least one chronic health condition, and about a quarter of reproductive-aged women reported having experienced an adverse pregnancy outcome such as miscarriage, stillbirth, infant death, or birth defects. A significant proportion of the population also reported being unable to rest or work effectively because of heat, air pollution, or truck/traffic noise in their neighborhood. More importantly, these residents are more likely to report having some health problems. Consistent with findings in Chapter 1, our data further suggests that residents who lived within 1,000 feet of a freeway, truck route, or major road had a higher prevalence of health problems compared to their counterparts. We also observed that living within 1,000 feet of a distribution center/warehouse was associated with a higher prevalence of health concerns.

4.5 RECOMMENDATIONS

Our two major recommendations from this chapter are as follows:

1. Although the 1,000 feet buffer best distinguishes the risks between residents inside and outside the buffer zone, our findings do not suggest that risks outside of 1,000 feet are insignificant. In fact, we recommend using a more conservative distance whenever possible, especially around more vulnerable receptors. Given significant health concerns in the region, it is critical to continue and strengthen efforts to reduce air pollution exposures in South Fresno.

2. Where appropriate, our goal is to engage South Fresno residents in the Fresno Truck Reroute Study's civic efforts. This is especially necessary given the significant proportion of South Fresno residents indicating concern with the environment, support for rerouting truck traffic, and interests in civic engagement.

GLOSSARY

AB 617: Assembly Bill 617 (AB 617) is a California state bill that was signed into law in 2017. The primary purpose of AB 617 is to address air quality issues in communities that are disproportionately affected by pollution. The law aims to enhance community air monitoring, improve air quality data, and involve local communities in the decision-making process to reduce air pollution. AB 617 establishes the Community Air Protection Program, which identifies communities with the highest cumulative exposure to air pollutants, referred to as AB 617 communities in this report.

Acute exposure: Short-term exposures to air pollution, typically within a couple of weeks. The idea is to see whether the exposures (like air pollution) have short-term health effects (i.e., within a few days of exposures).

Adverse pregnancy outcome: generally, any unfavorable health condition(s) that occurs during pregnancy. In this report, we chose to focus on preterm birth and infant mortality, two very serious outcomes.

American Community Survey (ACS): An ongoing survey conducted by the U.S. Census Bureau. It collects detailed demographic, social, economic, and housing information from a sample of households across the United States every year. This data source is commonly used in research that involves neighborhood or contextual factors.

Association: Correlation or relationship between two factors. Although associations do not always mean causation, in well-designed studies, associations estimate the causal relationship between two factors.

CalEnviroScreen: A tool developed by the California Environmental Protection Agency (CalEPA) to identify communities in California that are disproportionately burdened by multiple sources of pollution and are more vulnerable to environmental and public health hazards. CalEnviroScreen can be accessible at https://oehha.ca.gov/calenviroscreen.

California Air Resources Board (CARB): A state agency charged with protecting the public from the harmful effects of air pollution and developing programs and actions to fight climate change.

Department of Health Care Access and Information (HCAi): A state agency whose mission is to expand equitable access to quality affordable health care for all Californians through resilient facilities, actionable information, and the health workforce each community needs. Among the many things it does, HCAi collects data on all healthcare encounters in the state. This data source is unique and valuable for research efforts across the state.

California Department of Public Health's Office of Vital Statistics: An office within the California Department of Public Health which maintains birth, death, fetal death/still birth, marriage, and divorce records for California. The branch provides valuable data for population-based research due to the high state-level coverage.

Case-crossover analysis: A unique type of study design where people can serve as their own controls, which allows complete elimination of factors that can influence the quantifiable relationship. This is the reason we used this study for this study.

Confidence intervals (CI): The range of values that the true estimate can be if the sample/study was repeated infinite times. In this study, we used the 95% CI, which means that if the sample/study was conducted 100 times, the estimates will be in the range indicated 95% of the time.

Cardio-cerebral vascular diseases: Disease related to the blood vessels of the heart and brain.

Cumulative exposures: Exposures to a certain factor (like air pollution) over a period of time.

Emergency department (ED) visits: Medical encounters in emergency rooms across the state.

Excess cases: The number of cases of health outcomes as the result of a certain exposure (i.e., air pollution). Excess cases can also be interpreted as the number of cases that could be prevented if a certain amount of air pollution is reduced, which in this study is by 5 units.

Exposure: Refers to factors that may impact health. In this report, exposures refer to environmental exposures, including air pollution and proximity to pollution sources.

South Central Fresno Truck Reroute Study: A study aiming to identify, analyze, and evaluate potential strategies that freight-impacted communities might implement, in cooperation with the city of Fresno, to abate truck impacts. The study is led by the city of Fresno Public Works Department in partnership with the SJV Air District. More information can be found here: https://www.fresno.gov/publicworks/south-central-truck-re-route-study/

International Classification of Disease codes (ICD-10, ICD-9): A set of standardized codes used internationally to identify specific diseases. These codes are used mostly for billing reasons but are also an accurate way to identify specific health outcomes of interest from medical records.

Infant mortality (IM): Death of a live birth within the first year of life.

Lags: an indicator of delayed health effects. Lag 0 refers to health effects on the same day of exposure; lags 1-7 refer to health effects 1 through 7 days after exposure.

Odds ratio (OR): The ratio of the odds (estimates of the risks) in one group (usually those with the exposure) compared to another group (usually those without the exposure). OR is a common approach to quantify the relationship between exposures like air pollution and health outcomes.

Ozone: An odorless, colorless gaseous pollutant common in the SJV. This pollutant is formed from precursors including nitrogen oxides, volatile organic compounds, and heat/sunlight.

Outcome: Refers to health conditions or health risks (such as asthma, cardiovascular disease, stroke) that could be caused by or associated with an exposure; in this case, air pollution

Patient Discharge Data (PDD): These datasets contain all inpatient discharges from any licensed hospital in the state of California. The purpose of the data is to capture those people who ended up hospitalized for conditions evaluated in this study (asthma, cerebral cardiovascular disease).

$PM_{2.5}$: Fine particles with a diameter of <2.5 microns. These are small particles that are inhalable and have been known to cause many health problems worldwide.

Proximity: Refers to how close people lived from a source of pollutants, such as freeways, major roads, or truck routes). In this study, the proximity was evaluated by determining the distance from the closest source of pollutants.

Preterm birth: Birth occurring before 37 weeks of gestation. This is an adverse pregnancy outcome with potential serious short- and long-term consequences, because the baby is born too early and does not have enough time to develop inside the mother.

Prevalence: The proportion of the population with a specific health condition.

Risks: The probability or chance of having a health condition.

San Joaquin Valley Air Pollution Control District: A regional public health agency with the mission to improve the health and quality of life for residents through efficient and effective air quality management strategies. Website: https://ww2.valleyair.org/about/

Stratified analysis: An analysis that is separated by certain characteristics. For example, if an analysis is stratified by season, it means the researchers conducted the analysis separately by season to determine the effects of air pollution by season.

APPENDICES

Limitations of study

Chapter 1

We note that the study is limited by a few factors. First is the lack of residential relocation history in birth certificate data. It is possible that some pregnant people moved during the study period, causing potential misclassification of the exposure in the cumulative exposure analyses. However, we also know that although about 10-30% of pregnant people move during pregnancy, most relocated within a short distance.[80] Thus, residential relocation likely did not profoundly affect our results. Furthermore, in the acute exposure analyses, since we compared exposures within one month, it is unlikely that relocation had significant influence. The second limitation is the lack of personally monitored air pollution exposure. Since pregnant people have different daily patterns of activity, their actual exposures may not be the same as that at their residential address. A more accurate way to estimate exposure would be to personally monitor air pollution concentrations where people were during the day. Such an approach would not have been feasible for a large population. The use of modelled air pollution estimation is indirect but offers a more cost-effective strategy to learn how air pollution impacts pregnant people in Fresno. We also note that this study likely underestimated the true effects of air pollution on PTB and IM given the control period (or comparison group) is within the same person who are already highly exposed to air pollution because they live in the valley. The ideal comparison would be people who are exposed to significantly lower pollution, but given the fact that the SJV has more pollution compared to other regions within the state, the control group had inflated exposures. Lastly, given the lack of data on source-specific pollution (such as wildfire), our estimates were for general $PM_{2.5}$ and ozone exposures, regardless of the source. However, given the fact that sources like wildfires contribute a smaller proportion of long-term air pollution, we feel reassured that we have captured the impacts of major sources like traffic and transportation in the area, especially when our findings for pollutant-specific effects are consistent with distance from freeway and truck routes. Both are major sources of pollution. Furthermore, given wildfires are generally short-term and occur in the warm season, they do not explain the effects we consistently observed in the cold season for $PM_{2.5}$.

Chapters 2 and 3

The study has a few notable limitations. First, as with most air pollution studies, we did not have data on personal exposure. We relied on an air pollution model to estimate personal exposures. Since people move around during the day and may work in a different zip code than their residential zip code, there is a certain degree of misclassification. We expect this misclassification to underestimate the effects of air pollution, making our estimate rather conservative. We did not have identifiable information to track people over time and thus lacked the ability to assess event reoccurrence within the same person. Similar to Chapter 1, we note that our air pollution exposures captured all sources. However, given our findings for pollutant-specific effects are consistent with distance from freeway and truck routes, we feel confident that the estimates can be attributed to these sources.

In addition, the HCAi data only captured cases with medical encounters, which by nature are more serious. As a result, we were not able to capture minor instances that may not have been serious enough for people to end up in the ED or hospital. Lastly, all health conditions may be underreported with the hospital/emergency room data based on sociodemographic characteristics (uninsured, immigration status, etc.) as obstacles to reporting or seeking medical treatment.

Chapter 4

It is reassuring that the findings in this Chapter are aligned with previous analyses in this report. However, we note a few potential limitations in the data. First, the cross-sectional nature of the survey does not allow us to make conclusions about temporality between certain risk factors (i.e., reporting restlessness due to pollution) and health outcomes. In other words, restlessness could lead to health outcomes, but health outcomes could lead to restlessness. Nevertheless, the fact that exposed residents had more health concerns warrants attention. Second, given the rarity of many health outcomes, we were unable to implement more sophisticated models to further explore factors and mechanisms that can explain risks.

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